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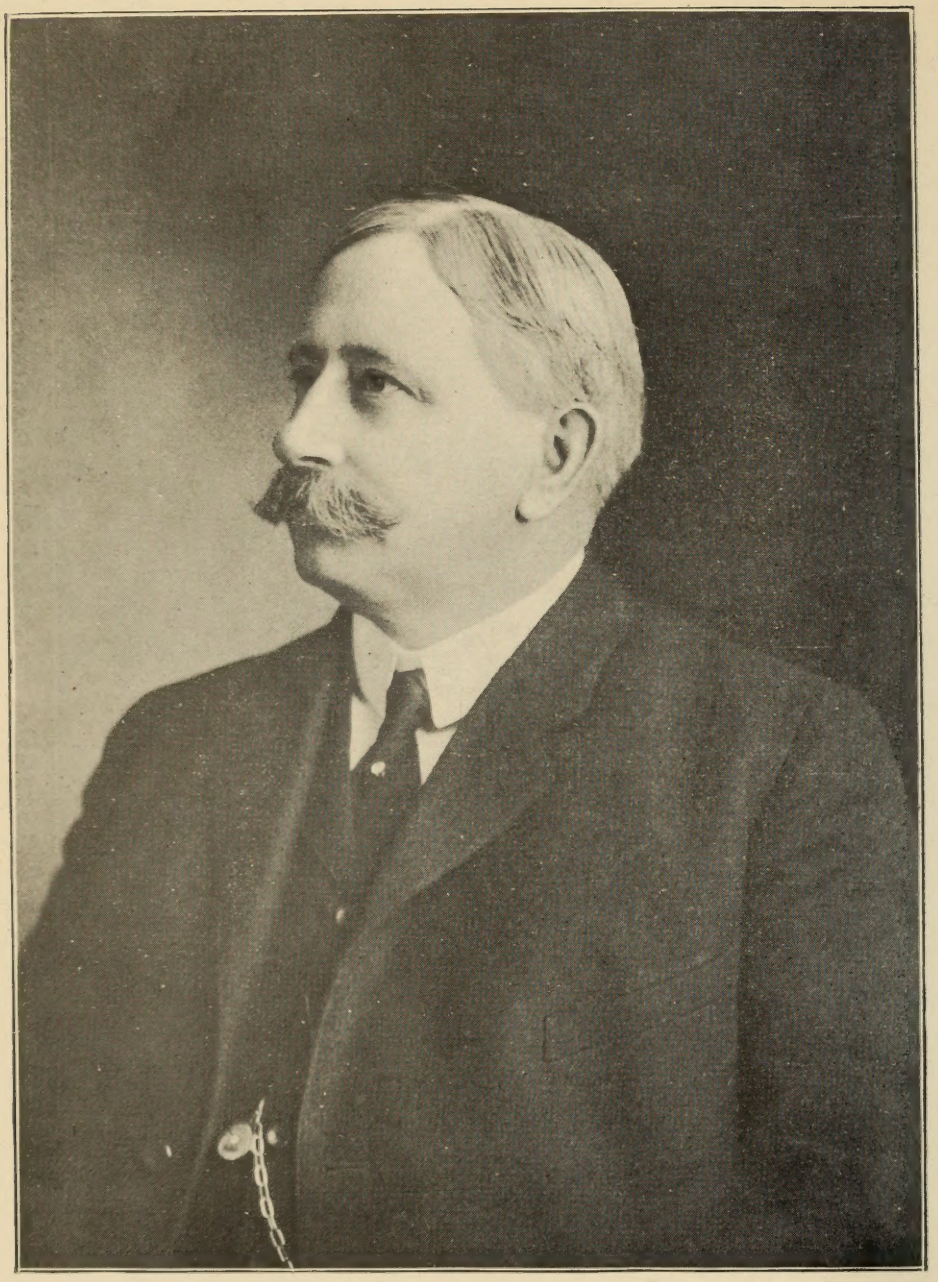

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OF THE

TWENTY-SEVENTH ANNUAL

CONVENTION

OF THE

American Water Works Association

HELD AT

TORONTO, ONT., CANADA

JUNE 17-21, 1907.

PUBLISHED BY THE SECRETARY

109645
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BOOK REVIEW.

The year has produced very little that is new in water works literature. Of the books predicted in last year's Review, the one by Messrs. Hubbard and Kirsted is of particular interest.

Mr. M. N. Baker in his paper read before the Association, entitled "Books for the Water Works Office," deplored the lack of books on Management. The deficiency has been filled by Messrs. Hubbard and Kirsted, in their book entitled "Water Works Management and Maintenance". Part I of this volume at first glance disappoints one, as it treats more of water supplies than of management, but this is proper, for the time is past when water works management and maintenance means merely forcing water into the mains and collecting for it at the faucets. Knowledge and proper handling of the source of supply is being considered more and more a part of the operation of water works.

The various sources of water supply are ably treated —there being chapters on ground waters, river waters and impounded waters. The selection and management of each supply is clearly treated in each chapter, the question of purification receiving considerable attention.

Another chapter in Part I is on Pumping Engines. This chapter treats of the selection, maintenance and records of pumping engines.

Part II deals with Management and Operation. The first chapter is on maps and records of work; followed by a chapter on extensions, locating fire-hydrants, handling and calking pipe, etc., tapping mains and putting in services; meters, their setting and care. The care of appurtenances, and tools. Examination and maintenance of the quality of the supply. Waste and means of detecting. Electrolysis—means of detecting and preventative measures. Fire protection—cost and efficiency. Accounts and bookkeeping. Financial management and making of rates. Rules and Regulations. Annual Reports and Franchises, and Depreciation.

There are throughout the book, many valuable tables and graphic diagrams; many of which are explained by working examples. The book is full of just the kind of information that water works superintendents and managers want; and all is conveniently arranged and completely indexed, so there is no trouble in finding the exact information needed on any of the subjects treated of. It is, in fact, a book that no water works manager should be without, whether he has charge of a small village plant or that of a large city.

There is much that is entirely new, and the older and well known forms, tables, etc., are arranged so as to be readily referred to.

About the only criticism of the book is that it does not go quite enough into detail work, does not tell of the little "tricks of the trade" of the veteran water works manager, a knowledge that would be of great value to the beginner or inexperienced superintendent. But this is rather more than could be reasonably expected in a work of this kind. As it is, it adds greatly to the knowledge of water works operation, and is well worth careful reading by all interested in the management and maintenance of public water supplies.

Published by John Wiley & Sons, New York; price $4.00.

PRESIDENT'S ADDRESS.

RATES FOR WATER SERVICE.

Dabney H. Maury.

The proper fundamental basis for all rates for water service is that the rates, when established, should be fair.

In what follows, an effort will be made to outline the principles which should govern the determination of the fair rate. As these principles are the same for municipally owned plants as for private ones, no distinction will hereinafter be made betwen the two.

Before the rates may be termed fair, these two conditions must obtain:

FIRST, The total yearly receipts from all sources must be just sufficient to provide

(*a*) Reasonable interest on the investment.

(*b*) Annual contribution to sinking fund to retire investment within a reasonable time.

(*c*) Proper annual contribution to sinking fund for depreciation.

(*d*) Legitimate operating expenses, including repairs.

SECOND, Each consumer must pay yearly, for the particular class of service that he receives, his just proportion of the above annual costs.

To fulfill the second condition, no service of any sort whatever should be furnished free.

It may be said that, in practice, neither of these two conditions can ever be realized with absolute exactness, and obviously the second is far more difficult to approximate than the first; but these considerations can in no way affect the fundamental principles involved.

A water works plant is almost always designed to supply fire protection as well as the water required for ordinary consumption.

Manifestly, the first cost and operating expenses of a plant built only to supply water for ordinary consump-

tion are very much less than those of a plant which also furnishes fire protection.

An average of available estimates made by eminent authorities shows that the annual cost of furnishing fire protection under average conditions is about fifty per cent of the interest and other fixed charges due to cost of construction of the works, and about twenty per cent. of the annual operating expenses.

Fair rates would therefore make the receipts from fire protection service sufficient to cover fifty per cent. of the fixed charges and twenty per cent of the operating expenses, the balance of fifty per cent of fixed charges and eighty per cent of operating expenses being provided by the rates for water supplied for ordinary consumption.

Fire protection service may properly be divided into two classes: Public Fire Protection, or that provided by the public fire hydrants on the streets; and Private Fire Protection, which is afforded to the owners of factories, stores, warehouses, or the like, by means of special service pipes of large size connected with the Water Department's distribution mains.

Pursuant to the second essential condition of a fair rate, neither class of fire protection should be furnished free, and the sum of all receipts from both classes should equal the annual expense properly chargeable to the fire protection feature of the works.

In practice, payments for public fire protection may best take the form of hydrant rentals; and whether the plant is municipally or privately owned is wholly immaterial in this connection. In either case, the Water Department is presumably a business concern, operated on a purely business basis, and it should receive the proper rates for public fire protection, paid out of the public funds.

There are abundant reasons why rates should be paid for private fire protection. The owner of the factory or other establishment so protected receives not only a yearly cash benefit measured by the reduction of his insurance premiums, but also a further substantial benefit in the form of protection against loss of business or other fire loss not

covered by insurance. This latter benefit, while not so easy to measure in dollars and cents, is often of greater value than the actual reduction in premiums.

The factory owner may argue that the same service connection which lessens his individual fire hazard also lessens to some extent the conflagration hazard of the community; but when all the facts are considered, this cannot well be said to be the case. The openings on his fire protection service are on his premises, and most of them are inside his buildings. They are not accessible for use by other parties. Should he happen to be dishonest enough to do so, he could draw, without detection, large quantities of water for uses other than fire protection. Should a fire once gather headway on his premises, enormous amounts of water might be drawn from thousands of sprinkler heads, or as a result of the breaking of his large service pipes by falling walls, or in other ways; and the quantity of water so drawn might readily be enough to seriously hamper the City Fire Department in its efforts to check a conflagration. To sum up, the factory owner may be said, in effect, to benefit exclusively, and to a substantial extent, by reason of a special service which the Water Department is at expense to provide, and for which he should therefore pay.

It is not possible to satisfactorily meter his fire service; and if it were, to base his rate on the value of the water actually consumed to extinguishing fires would be as unreasonable as it would be to say that the value of a navy is nothing more than that of the ammunition which it expends in actual warefare.

The fixing of rates for private fire protection is so intricate a problem, and involves consideration of so many points, that no fixed rule can be laid down that will fit all cases. It is believed that a reasonable sliding scale of rates for such service might be arrived at as follows: A minimum rate for the smallest size of fire service pipes, and larger rates for larger service pipes, the rates for each size of fire service pipe to bear some approximately uni-

form relation to the special benefits derived by the private interests protected.

Rates for water for purposes other than fire protection are of two general classes, fixture rates and meter rates. Originally all water was sold at fixture rates, but the necessity for checking waste, and the recognized inequity of fixture rates as applied to individual cases, have brought about the introduction of meters, which is now going on at a constantly increasing speed.

The earliest fixture rates were necessarily established largely by guess; and later ones have been fixed, sometimes by taking the average, and sometimes by picking out the lowest of all the guesses made by previous guessers. Little or no account was usually taken of the differences in cost of furnishing water in different locations and under varying conditions.

That fixture rates are not now, as a rule, excessive, is indicated by the fact that when all legitimate expenses are charged up, few municipally—owned plants earn large profits, and that the securities of private water companies are no longer so eagerly sought by investors as they were some years ago. The objection to fixture rates as a basis of the value of water service does not lie in the fact that they cannot be made, in the aggregate and for any one city, as a whole, as equitable as any other rates; for this is not only possible, but is a condition which actually obtains, within reasonable limits, in many cities. But with fixture rates, no close discrimination can be made between individual cases; and they therefore fail to fulfill the second essential condition of a fair rate. Furthermore, they fail to check waste and leakage.

These considerations naturally lead to the adoption of meter rates.

In almost every city, the introduction of meters, if accompanied by the establishment of proper rates, can be made to result in benefit to the Water Department as well as to the consumer; and it is possible, with meters, to make a closer approximation to the fair amount to be paid

by each individual consumer than can be made without them.

The cost of the introduction of meters, and of their subsequent maintenance and operation, will, with proper rates, be more than offset, and without hardship to the consumer, by the savings in pumping expenses and in the costs resulting from extensions to plant, which would otherwise have to be made.

The function of the meter is two-fold: first to check waste, and second, to measure the water used by each consumer, with a view to making his annual payments bear a just proportion to the total fair annual receipts from the works. To treat the meter simply as a device by means of which certain individual consumers may reduce their rates below the fair amount, leaving other consumers to make up the loss, is to defeat its honest purpose.

In order that the meter may properly perform its two-fold function, it is absolutely essential that the meter rates be established on a proper basis. In view of the ever increasing use of meters, no more vital problem to-day confronts the manager of a water department than the determination of what these rates should be in his city; and it is a problem whose solution demands the very highest degree of skill, careful study of all the conditions and a wide experience in the financial management of water works.

Nothing is more fallacious than the oft-repeated argument of some unthinking advocates of the universal introduction of meters, that when a man buys water by the gallon he pays for what he gets.

Each consumer whether he use little or much water, enjoys the benefit of a water service, always at hand, always convenient. This benefit is the element which is usually termed the "Readiness to Serve", and the expense to the Water Department of its readiness to serve is always far greater than the mere cost of pumping and distributing water. Furthermore, the fixed charges and operating expenses for each meter service amount to several dollars per annum; and this expense, together with a sum sufficient to cover the "Readiness to Serve", is properly

chargeable to each consumer, large or small, before the rate per gallon can fairly begin to apply.

To provide for these two expenses, the first method which naturally suggests itself is the establishment of a minimum meter rate.

Here again there is a pitfall. If this minimum be too small, it will not accomplish its purpose. If it be too large, or if the rate per gallon for small daily uses be too small, the average domestic consumer may draw far more water than he actually needs without paying more than the minimum rate; and this condition will destroy the usefulness of the meter as a means of checking waste.

To set meters wholesale, without due regard for the foregoing facts, would not only work an injustice to some classes of consumers, but might mean financial disaster to the Water Department; and this in turn would be a misfortune to the whole community.

To develope the full efficiency of the meter as a means of checking waste, and to make each consumer, large or small, pay his fair share of the total receipts of the works, meter rates should be established about as follows:

(*a*) The minimum rate should be nearly large enough to provide for the "Readiness to Serve," as well as for the added expense of the meter service.

(*b*) There should be a sliding scale of rates for measured water.

(*c*) The highest rates in this scale should be so adjusted that the average domestic consumer could draw, without exceeding his minimum rate, only enough water for his reasonable requirements, so that the incentive to avoid waste might always be present; and the lowest rates in the scale should be such as to encourage large consumers to patronize the water department, the profits from this patronage being, of course, ultimately applicable to the lowering of rates to all consumers.

From all of the foregoing, it will be seen that rates of all classes are co-related. The total receipts should just provide for the total legitimate expenses, as enumerated in the definition of the first essential condition of a fair

rate. Each class of service should be made to furnish its quota of the total receipts from all classes of services; and each individual consumer should pay his just proportion of the total receipts from the class to which he belongs.

It is admitted that this ideal state of affairs can never be fully realized in actual practice. But many notable instances of mistakes already made in the establishment of rates, furnish abundant proof that a careful, sane and intelligent study of conditions will do much towards approximating the desired results.

METERS AND METER SYSTEMS.

W. Volkhardt.

The water meter has long since passed the experimental stage. Its use is a necessity for more than the one reason of curtailing waste. The American people have recently been imbued with the "square deal" idea and are demanding it in all propositions and undertakings, and it is this idea that appeals to them in the introduction of water meters when the plan has been placed before them in a plain and comprehensive manner.

To install a successful meter system requires expert knowledge and careful study of the local situation and conditions, in order to be able to weigh all those conditions and do justice to the greatest number. When a water works system is about to be designed the preliminary step is to engage the services of an experienced Engineer. The same thing should be done when a meter system is contemplated. This necessary requirement has been too often neglected, and hence, many water works are not getting the results out of their meters that they could have realized otherwise, but it is being done now and the results are much more satisfactory.

Such a move is no reflection upon the ability of the local superintendent; he has enough to employ his time keeping the plant running smoothly. All new construction should be in charge of an outside experienced man, except in cases where the city is large enough and the work sufficient to employ such a man permanently, and even in that case if he has but a limited knowledge of the subject he should be sent on a learning expedition.

The only correct way, to my mind, to introduce water meters to the public successfully is to install a universal system. Don't start off by placing one case of meters; that is your first obstacle on the road to success. It is discrimination because in that way only a

certain few have been selected and, in most cases, these are consumers who either use a great quantity of water, or the business is such that it is difficult for him, or them, to control all of the waste. The result is a large increase in the bill. This fact is widely advertised and your efforts for the placing of more meters are strongly antagonized. This, also, sometimes leads to your reducing the rate you had originally decided upon, and when you have reached the point of metering the Domestic supply you see your annual revenue decreasing and to prevent it you are forced to raise the rates. I don't have to tell you what that means; you know. My suggestion is, start right, consider everything at-the-making-of-the-rate point. If you can't do this, call in the man who can, it is worth it.

To those of you who are connected with municipal plants and cannot get appropriations for a universal system, my suggestion would be to have a general ordinance passed calling for every tap to be metered, to wit:

GENERAL ORDINANCE.

"Be it ordained by the Select and Common "Councils of the City of . . . and it is hereby or- "dained by the authority of the same. That a wa- "ter meter be placed upon every service pipe con- "nected with the water works system".

After this ordinance, or one to the same effect, has been passed, offer Resolutions from time to time covering certain classes of business, to wit:

RESOLUTION.

"Be it resolved that water meters be placed up- "on all hotels, saloons, livery stables, motors, court "house, jail, railroads, manufacturing establish- "ments, and buildings containing steam boilers on "or before . . . . . .

The above Resolution can be condensed:

"Be it resolved that water meters be placed at "once or as soon as practicable, on all manufactur- "ing and commercial establishments."

Now-a-days we divide the consumers into three classes, Manufacturing, Commercial and Domestic. The word Manufacturers explains itself. The word Commercial covers a vast field of enterprises. The word Domestic takes in the private dwellings. Following a resolution to meter the Manufacturers and the Commercial consumers a third resolution can be introduced to cover the Domestic supply, something to this effect: "to meter the balance of the unmetered taps within a given time," and you will then be on the road to a Universal System.

To make a meter system popular, you must pursue the give-and-take policy. The revenue from the manufacturer and commercial consumer will invariably increase, while the revenue from the Domestic consumer will invariably decrease; therefore, it is much better if an entire city or town can be metered at one undertaking. Under this plan there will be a greater number with reduced water bills, and they will far out number those whose bills have increased.

Right here is where the people recognize the "square deal" and the meter system will then become popular.

For several years past I have studied this subject closely and have visited several hundred cities and towns. In some places I have found a Universal System, in some a partially metered system and in others no meters at all. Recently there was installed a Universal System in a town having 200 taps. The introduction of meters in this town corrected quite a number of abuses that could not have been remedied otherwise, and secured an increase of some eight new taps. In this particular instance there were practically no records. The department was following the plan of bunching a consumers' account. For instance, if John Brown owned three or more houses, his name appeared only once on the Register with no address. Sometimes one of those houses became vacant. He naturally had one of those houses charged off but ne-

glected to report when that house was occupied again. With a meter on each house he can't do this. Accounts were opened with tenants, in many instances causing changes on the books as they came and went, and loss of revenue because they were not responsible. Another abuse eliminated was that we found some families being supplied from neighboring hydrants. This is how the town secured the eight new taps mentioned above.

It is needless to say to you that the meters stopped the waste and thereby increased the amount of water available and improved the fire pressure. Strange as it may seem, there are more meters being installed, to my knowledge, on gravity plants than on pumping plants. I inquired into this matter and found that because there is no expense to the town to impound the water the citizen thinks that he does not have to recognize the waste item.

One of the most important features of a meter system that appeals to the consumer is the fact that with a meter on his service he is very independent, he can do as he pleases with the water after it has passed through his meter, he can add many spigots without asking permission of anyone, he can use a hose to his heart's content, the city's authority ending at the meter.

Recently certain town officials thought seriously of passing an ordinance for the regulation of hose use on metered premises. But before putting it into effect the Water Company's Attorney and the City Solicitor held what they were pleased to call "a friendly suit" on the question. It was finally decided not to try to regulate the use of hose on metered premises, it being conceded that the company's authority ended at the meter. The same would apply to a municipal plant.

The above brings to my mind a meter case that got into Court, the particulars of which were told me by one of the principals, which may be of interest to you. A manufacturing concern had increased the capacity of its plant until it reached into the corporate

limits of the city adjoining. The water services were extended into the new parts. The city adjoining raised the point that the water supply for the new additions would have to be taken from its mains. The manufacturer objected to this and the result was a law suit. The case was tried and a decision rendered "that the purchasing and selling point was at the meter and that the buyer could conduct the water into any part of his premises."

Another important feature of a meter system is the time of reading meters. I find that in some places the meters are read only once in six months, many are read only once every three months others are read monthly. I think the entire service would be greatly benefitted if all meters were read monthly, but this does not mean that bills should be rendered monthly. To illustrate: there are times when a meter stops registering. Suppose it stops the day after it has been read. It remains so for three or six months as the rule may be, you have lost that registration or you average the bill. I think you will agree with me that that plan is very seldom satisfactory to either party, but had you read the meter monthly, you would have lost but one month's registration, or had a problem just one sixth or one third the size of the former to adjust.

Service pipes wear out and fixtures become leaky. In many cases the consumer is not apprised of this until he receives his bill, no matter how careful or vigilant a person may be with such matters. The leak may be discharging water into an underground or covered passage. For argument sake, we will suppose he is a poor man (I make this illustration because I once had such a case to decide) he claims it is an utter impossibility for him to pay the bill, to force it upon him means a hardship to his family, at the same time taking the position that he did not get the benefit of the water that leaked away. You investigate and decide to reduce the bill to what it was the corresponding quar-

ter. You have lost again. But on the other hand, had you read the meter monthly the bill would have been of such an amount that to insist upon its payment would not be a hardship to the consumer, and you are in a much stronger position to get paid for your leaks, having notified the consumer at the earliest practicable moment. It is to be understood that in case of a leak you should notify the consumer at once by letter or postal card provided for the purpose.

Such cases as the two just mentioned prevent many Managers getting appropriations on one hand, applications for more meters on the other, and retard your meter system from growing and keeping pace with the increased consumption as it should. If you have to rebate a large portion of your leaks, what benefit are your meters?

Some may think it will cost more to read meters monthly than if read quarterly. Not necessarily so. Divide your system into two or several districts to the number of men available to get over the ground in one day, or two if it be a large system. Draft into this service a clerk, tapper or foreman. Take off your fireman for a day, the engineer can do his work, make all other business wait on that one day. You can do it; it is being done in some places, and will continne to be done, and it will not add one cent to the annual maintenance of the meter system.

Meters play an important part in the health of the city, in connection with the sewer system. I think it fitting to conclude my paper with a few words on this subject taken from one of our Trade Journals.

The introduction of meters is sometimes antagonized by people who are not familiar with the subject and delay a well meaning and beneficial project. I refer to the medical profession who at times raised the point that the use of meters will curtail the use of water and bring about unsanitary conditions, while experience has shown just the reverse. Much has already been said and written upon this subject.

Examination of sewer systems of an unmetered city show constant streams of water discharging into the sewer from house drains. A continuous stream of water coursing through a sewer will not keep it clean but will pack the sediment and solid matter and this must be cleaned out by hand power, while on the other hand if meters were used the constant stream, which usually comes from a leaky ball-cock on the premises, will cease and the volume of water set free by the discharge of the water closet tank will sweep everything before it and keep the sewers much cleaner. A few sewer flush tanks built into the sewers at the proper places and discharging three or four times every 24 hours are a great help in keeping sewers free of sediment and solid matter.

Some people think sewers do not retain sediment, this is a mistake, even water mains under pressure and carrying their full capacity of water, have to be "blown out" periodically because they contain sediment. Meters and Flush Tanks will prevent the accumulation of solids in sewers much better than anything else and at the least expense.

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THE COST OF METERS AT ROCHESTER, NEW YORK.

Geo. W. Rafter.

General Statement.—In 1896, the total disbursements charged to the Water Works fund were $421,369.93, while in 1904, the total disbursements were $438,127.05. Without going into the various details, these figures show in a general way that there has been no reduction in the expenses of the water works since 1896 and in view of the betterments which have been made, there has been, as might be expected, a small increase in the expense. If, however, we examine the meter accounts, as given in detail in the annual reports, the statements show that there has been a reduction in the expenses of the meter department. In 1896, the total expenses of the department were $27,602.63. There were set during that year 930 new meters. There is deducted from the total expenses of the department, on account of the amounts received from the sale and repairs to meters, $7,564.81, leaving as the net expenses of the department, $20,037.82. The number of new meters purchased is not stated, but their total cost is given at $8,729.30, and presumably the number actually purchased was not far from 930, the number set. The figures indicate that there were a few more purchased than were set.

In 1904, the total expenses of the meter department were $29,145.67, or with double the meters set, the total increase in the expenses of the department was only $1,543. Deducting from the total expense the amount received for sale and repairs to meters of $13,079.41, we have the net expenses of the department as $16,066, or nearly $4,000 less than in 1896. This is certainly to the credit of the meter department that they have been able to bring down the running expenses to this extent.

Effect of a Meter in Reducing Cost of Water.—Reports differ as to the effect of a meter in reducing the cost of water. In some cases, it is stated to increase it, but as a general principle, it is considered to reduce it. The following are the figures of cost for one metered service: During the year 1902, the cost of water was $7.06, while during the year 1905, it was $9.10. So far as known, the use of water was substantially the same in both years. The flat rate of the same service unmetered is $12 per year. In opposition to the indications of this single meter, however, the statistics herewith cited as to 2,733 meters in the year 1896 are to be considered.

Does Not Follow that the Use of Meters in Rochester will Reduce the Use of Water.—The following statistics are cited to show that it does not follow at all that an addition to the domestic meters will reduce the quantity of water used—indeed, the statistics cited show exactly the contrary. In the 19th Annual Report of the Executive Board, there is at page 199, a table of the uses of metered water in 1891, 1892 and 1893. The complete statistics are not given for 1891, but they are for the other two years. It appears from these that the accounts of 1,093 domestic meters were taken in 1892 and 1,357 domestic meters in 1893. The total use of metered water from the 1,093 domestic meters in 1892 was 18,023,595 cubic feet, while the total use of metered water from the 1,357 domestic meters in 1893, was 23,118,705 cubic feet. The use of water for the entire year per meter was in 1892 for 1,093 meters, 16,490 cubic feet, while in 1893, the total use of water per meter from the 1,357 meters was 17,037 cubic feet, an increase in the second year of 3.2%. The following tabulation in regard to these domestic meters is of interest:

Year	Number of Meters.	Total use of water. Cubic feet.	Use per meter. Cubic feet.	Use per meter. Gallons. (7.5 cu. ft. per gallon)	Gallons per capita per year (On basis of 5.4 persons per meter.)	Gallons per capita per day
1892	1,093	18,023,595	16,490	123,675	22,903	63
1893	1,357	23,118,705	17,037	127,778	23,663	65

The preceding tabulation is especially interesting when we learn that the total use of water in 1892 was only 60 gallons per capita per day and in 1893, 57.6 gallons per capita per day. The official figures show, therefore, that the metered water was in 1892, 3 gallons per capita per day in excess of the average and in 1893, 7.4 gallons in excess.

Table of Metered Water in Rochester.—In the 24th Annual Report of the Executive Board at page 42, there is a table showing the daily average consumption of water through meters for the years 1891, 1892, 1893 and 1896, classified as domestic, commercial and manufacturing. The average use in 1896 per meter per day was 534 gallons. There is a table in the 5th Annual Report of the Department of Public Works for 1904, at page 49, wherein the ratio of population to number of service pipes in 1896 is given at 5.3. Dividing 534, the use per metered service, by this coefficient of 5.3, gives the use of metered water in 1896 at 100.8 gallons per capita per day. The total number of meters from which this is derived is 2,733. The nub of this matter will be appreciated when I state that the average total use of water—including both metered and unmetered—per capita per day in 1896 was 77.8 gallons. As these statistics are exceedingly important, I will repeat that in 1896 the average use of water per day through 2,733 meters was 534 gallons per meter and that this figure on the ratio of population which is found to be true in the city, represented a use of 100.8 gallons per capita per day, while the average total use of water in 1896, of all kinds, was for the entire population, 77.8 gallons per capita per day.

The table referred to in the 19th Annual Report of the Executive Board also gives the use of water from 303 manufacturing meters in 1892 and from 299 manufacturing meters in 1893, and shows a reduction in the use of water in the second year, but this has no significance until we know whether the four meters omitted were large users. Moreover, the use of water for purely

manufacturing purposes will vary from year to year, so that these particular statistics have still less significance.

In the year 1892 the total use from 1,618 commercial meters was taken at 13,690,868 cubic feet, while in 1893, 1,617—one less—commercial meters showed a use of 13,932,121 cubic feet, an increase in the second year. If these statistics show anything, they show not only that meters do not necessarily reduce the use of water, but further that for the particular years and number of meters considered, the use of water has on the whole increased, except in the case of the manufacturing meters, where, in the absence of information as to the meters which are omitted from the account the second year, the statistics are without significance.

Cost of Removing, Repairing and Resetting Old Meters.—The following tabulation shows the cost of removing, repairing, and resetting old meters, 1893-1905, inclusive:

Year Ending	Numb'r of Meters removed	Cost of removing, repairing and resetting old meters, including proportionate part of salary of superintendent and meter clerk.	Cost per meter.
Apr. 3, 1893	772	$3,453.05	$4.47
Apr. 2, 1894	659	3,278.70	4.98
Apr. 1, 1895	846	3,401.39	4.02
Dec. 31, 1895	649	2,876.29	4.43
Dec. 31, 1896	615	4,150.49	6.75
Dec. 31, 1897	704	3,727.65	5.29
Dec. 31, 1898	505	2,668.52	5.28
Dec. 31, 1899	923	4,056.03 (a)	4.39
Dec. 31, 1900	720	4,123.95	5.73
Dec. 31, 1901	595	3,306.35	5.56
Dec. 31, 1902	724	2,908.39	4.02
Dec. 31, 1903	765	3,653.73	4.78
Dec. 31, 1904	1209	4,537.16	3.75
Dec. 31, 1905	1197	4,492.13 (b)	3.75
Total	10883	$50,633.83	Mean $4.80

a—Salary of clerk estimated.

b—Taken proportionate to 1904.

Cost of Setting New Meters.—The following tabulation shows the number of new meters set, together with the cost of setting and testing the same, 1893-1905, inclusive:

Year Ending	Numb'r new meters	Cost of setting and testing new meters, including proportionate part of salary of superintendent and meter clerk.	Cost per meter
Apr. 3, 1893	374	$2,060.38	$5.51
Apr. 2, 1894	388	1,889.07	4.87
Apr. 1, 1895	332	1,979.42	5.96
Dec. 31, 1895	1135	2,102.96	1.85
Dec. 31, 1896	930	2,945.20	3.17
Dec. 31, 1897	581	2,326.36	4.00
Dec. 31, 1898	760	2,736.47	3.60
Dec. 31, 1899	804	1,798.54 (a)	2.24
Dec. 31, 1900	831	1,699.71	2.04
Dec. 31, 1901	709	1,837.33	2.59
Dec. 31, 1902	898	2,088.56	2.33
Dec. 31, 1903	907	2,466.54	2.72
Dec. 31, 1904	1066	2,355.13	2.21
Dec. 31, 1905	1782	3,946.38 (b)	2.21
Total	11497	$32,232.05	Mean $3.24

a—Salary of clerk estimated.
b—Taken proportionate to 1904.

The following explanation is given relative to the statistics of the two preceding tabulations. In neither case do the figures represent the full cost either of removing, repairing and resetting old meters or the cost of setting and testing new meters. The item of testing meters is all apportioned to new meters, although both old and new meters have really been tested, but as there is no way of telling the proportionate part ,this item is all apportioned, as stated, to new meters. The following items are not included in either tabulation: Inspection of meters, general expense of maintenance, examination of metered services, cutting nipples and

pipe, work of repair department, miscellaneous work, etc. Were these items included and properly apportioned, the expense of removing, repairing and resetting old meters, as well as the cost of setting and testing new meters, would be considerably increased. In neither case, therefore, does the last column, Cost per meter, represent the total cost to the municipality.

Cost of General Expense of Maintenance.—As a reason for omitting these several items, they are perhaps all in the nature of general expense of maintenance and apply to all the meters set in the city. The totals of these several items, together with the expense per meter for the total number in use, are accordingly given in the following tabulation:

Year Ending	Number of meters in use at end of year.	General Expense of maintenance	Expense per meter
Apr. 3, 1893	3,460	$2,549.99	$0.74
Apr. 2, 1894	3,724	3,254.90	.87
Apr. 1, 1895	4,043	3,359.11	.83
Dec. 31, 1895	5,157	2,292.01	.44
Dec. 31, 1896	6.005	3,928.67	.65
Dec. 31, 1897	6.497	3,572.29	.55
Dec. 31, 1898	7,227	1,437.17	.20
Dec. 31, 1899	7,994	1,357.38	.17
Dec. 31, 1900	8,752	1,183.78	.14
Dec. 31, 1901	9,435	1,722.84	.18
Dec. 31, 1902	10,310	1,713.11	.16
Dec. 31, 1903	11,201	1,319.78	.12
Dec. 31, 1904	12,260	1,101.10	.09
			Mean $0.37

By studying the preceding tabulations, we learn that in the fourteen years, 1892-1905, inclusive, there were 10,883 old meters removed, repaired and reset, the repairs varying in expense from $6.75 to $3.75 per meter. During the same period there were 11,497 new meters set at an average expense of $3.24 per meter. The

figures indicate that once in about twelve to fifteen years a meter has to be removed and repairs made in the way of defective gears or piston rods, or something else, at an expense about as indicated. In order to show the various causes for repairs, the following statement from the 5th Annual Report of the Department of Public Works of the causes of removal during the year 1904 is herewith given. During this time, there were 171 meters repaired on the premises which are not included in the statement:

Cause of Removal.	Number.
Leaky stuffing boxes, flanges or couplings	37
Stoppages due to rust and mud	160
Broken or defective intermediate gears or piston rods	160
Broken or defective dials or dial gears	49
Injured by frost	105
Broken by frost	176
Injured by hot water or steam	30
Worn out	1
Noisy action	7
Examined for accuracy	43
Exchanged for meters of larger size	3
Exchanged for meters of same size	0
Removed because of change of pipe	18
Removed from vacant premises	69
Pistons or discs worn out or broken	116
Stopped and needed refitting of piston or disc	172
Minor causes not mentioned	63
Total	1,209

Limit of Economic Metering.—It is perhaps unnecessary to point out that with 35,000 meters set, there would be at least $100,000 expense connected with this mere repairing of meters every twelve to fifteen years. Moreover, there is one matter to which we may refer at this place, namely, as to the number of taps for service pipes in comparison with the number of services

actually in use. The number of services actually in use in 1904 was 33,170, while there were taps for services to the amount of 37,682, or over four thousand more taps for services than services actually in use. Consequently, the number of meters which will require to be set will approximate 40,000, this being the probable number of taps in 1908. It seems clear, therefore, that the limit of economic metering is about reached in Rochester. It is considered that anything over twelve to fifteen thousand meters is unnecessarily adding to the expenses of operating the water works.

Standard Meter Curve.—In order to show that this is true, I will refer to a diagram plotted by J. R. Freeman and given at page 70 of his report upon the New York water supply made in 1900. This diagram shows that taking a considerable number of cities and summing up the general tendency, the application of meters to 50% of the services may be expected as an average to reduce the use of water to about 65 gallons per capita per day. If 100% of the services are metered, the average use of water will be reduced to 55 gallons per capita per day. With no services at all metered, there may be a use of from 175 to 250 gallons per capita per day.

This curve has been recently replotted by the Water Department of the City of Pittsburgh with more extensive data than used by Mr. Freeman, without changing it in any important particular. It may be considered, therefore, the standard meter curve. It shows that in Pittsburgh, starting with the present use of water of 253 gallons per capita per day, the use will be, with 50% of the services metered—metering to go on at the rate of 13% per year—180 gallons per capita per day.

Application of the Curve to Rochester.—Let us consider for a moment the application of this curve to conditions in Rochester. In 1905, the use of water was 85.7 gallons per capita per day, with 41% of the services metered. Probably the effect of metering 50% of the services will be to reduce the daily use of water to about 75 gallons per capita per day, which is 10 gallons more

than the indications of the curve, and which 10 gallons excess is partly due to the character of the commercial and manufacturing uses here at Rochester. For this particular city, therefore, the metering of 50% of the taps will not reduce the use of water to 65 gallons per capita per day, but will still leave it at about 75 gallons. Consequently, the metering of 100% of the taps will not reduce the use of water to 55 gallons per capita per day, but will leave it perhaps 10 gallons more, or 65 gallons. That this conclusion is rational is easily deduced from a study of this standard meter curve.

Meter Statistics of Providence.—Providence is frequently cited as a meter town where meters are especially effective in reducing the consumption of water, but looking over the statistics for the year 1904, not very much consolation for universal metering is found therein.

Population of Providence in 1904, including 14,900 supplied in the suburbs and outside of city	207,900
Population of city proper	193,000
Population of Rochester in 1904	175,000
Total number of services in use in Providence in 1904, including suburbs	23,381
Total number of services in use in Rochester in 1904	33,170
Greater number in Rochester than in Providence	9,789
Total average daily use of water in gallons in Providence in 1904	13,857,087
Total average daily use in Rochester in 1904	15,237,773
Difference, in gallons	1,380,686

Average daily use of water per capita per day in Providence in 1903, in gallons	65
Average daily use per capita per day in 1904	67
Increase from 1903 to 1904, in gallons	2
Average daily use of Hemlock Lake water per capita per day in Rochester in 1903 in gallons	80.0
Average daily use per capita per day in 1904 in gallons	75.5
Decrease from 1903 to 1904 in gallons	4.5

These last figures show that in Rochester, with 12,000 meters, the use of water happened to decrease 4.5 gallons per capita per day from 1903 to 1904, while in Providence, with a total of 20,489 meters, the average daily use of water happened to increase 2 gallons. These facts are sufficient to show that there are other reasons for increase or decrease in use of water which are far more potent than the use of meters.

Providence reports are silent as to the statistics of meters although there is some information on the cost of metering at Providence in a paper by Edmund B. Weston in the Journal of the Association of Engineering Societies for August, 1888. The statistics there are brought up to the end of 1887, but since this information is twenty years old, it is not very applicable in 1907.

The explanation of the difference of 1,380,686 gallons in the average daily use of water at Rochester and Providence must, therefore, be sought in some other direction than the difference in number of meters. The real reason is partly difference in manufacturing and in habits and customs of the people and partly in the fact that in Providence the ratio of inhabitants to number of services in 1904 was 9.0, while in Rochester this ratio was 5.2—that is to say, there were in 1904, 9.0 people

per service in Providence and in Rochester only 5.2 people per service. Since leakage and wastage, either with meters or without, will be in proportion to the number of services, we find a very salient reason why the use of water at Rochester is larger than at Providence. Personally, I have no doubt that if nine persons were supplied from each service in Rochester instead of 5.2 persons, the use of water would be not far from what it is in Providence, even though in 1904 there were nearly 10,000 less meters here than there.

Effect of Construction of Two-story Flats now just Beginning in Rochester.—One point may be mentioned in this connection, that a great proportion of the houses building in Rochester at the present time are two-story flats for from two to four families. The effect of the construction of a considerable number of such will be to increase the ratio of inhabitants to number of services and hence to reduce the use of water. Therefore, let the meter department not make the mistake of supposing that a small reduction taking place in the next few years is due entirely to meters—it will be partly due to this change in form of construction.

Number of Inhabitants per Service.—This matter of the number of inhabitants per service, or the ratio of population to services, is an exceedingly important one ,although thus far in considering use of water, it has been mostly overlooked and in consequence all the statistics which I have seen are of little value because they chiefly give the credit to metering which is rather due to the considerable number of inhabitants per service. I shall not discuss this question very extensively, but wish to cite the statistics of a few European cities, as well as New York city, in comparison with Rochester.

Berlin.—In Berlin, there is an average of over seventy persons supplied by each service pipe, while in Rochester there is an average of 5.2 persons supplied per service pipe. The opportunities for loss and leakage at Rochester, therefore, are over thirteen times as

great as at Berlin, and accordingly we need not be surprised to learn that the total amount of city water supplied in Berlin is about 20 gallons per capita per day, a result which is not due to the use of meters—although every service in Berlin is metered—but which is chiefly due to the large number of consumers per service.

Moreover, by sinking a well anywhere in the city, gravel is found in a few feet in which there is an abundance of water. Manufacturers and brewers use water from this gravel almost exclusively, so that it is estimated that water from wells consumed in Berlin amounts to from 10 to 12 gallons per capita per day, making the total use of water for all purposes about 30 gallons per capita per day.

In order to show how little effect meters have had in Berlin, the following statistics of that city are included: In 1870, the number of consumers in Berlin was 423,915, with an average of 64.2 persons per service; the average daily consumption per capita was 18.7 gallons; and the number of meters in use was 1,203. In 1890-91, the number of consumers was 1,427,148, with 66.6 persons per service; the average daily consumption per capita was 18 gallons; and the number of meters in use was 21,625. In 1895-96, the last year reported, the number of consumers was 1,719,183, with 72.0 persons per service; the average daily consumption per capita was 18.2 gallons; and the number of meters in use was 25,428. These statistics tell the story at once and show that the large number of consumers per service is the real reason why the use of city water is so low in Berlin.

Glasgow.—In Glasgow, with 4,000 meters in use, the daily consumption of water per capita is about 68 U. S. gallons, the total population supplied being a little over 1,000,000. The use of meters is not encouraged to any great extent, the municipality not enforcing their use except in some special cases.

Liverpool.—The population supplied with water in

and around the city of Liverpool in 1901 was 1,018,174 The area of this entire district is not known, but the area of Liverpool proper, excluding the area occupied by the docks, etc., is 4,477 acres (7 square miles) on which the density of population is perhaps 125 per acre, or at the rate of something like 80,000 per square mile. Liverpool enjoys the distinction of being the most densely populated city in Great Britain.

Excluding the outside population, the use of water in Liverpool proper in 1901 was 37.4 U. S. gallons per capita per day. Meters are only used at places where water is sold for trade purposes or to ships and for workhouses and industrial schools, amounting to a daily use of a little over 10 U. S. gallons per capita. The number of inhabitants per service is not known, but it may be approximated by considering the relative statistics of Berlin and Liverpool. The population of Berlin is given in 1896 as 1,719,183 and the area of the city at 14,562 acres. Hence, there are 118 persons per acre or 75,520 per square mile in Berlin, while in Liverpool there are about 80,000 persons per square mile. The number of inhabitants per service must, therefore, be somewhat greater in Liverpool than in Berlin, or at the rate of perhaps 75 per service.

Berlin and Liverpool Contrasted.—The total daily use of water in Berlin, including water not taken from the city water works, is about 30 U. S. gallons per capita, while the number of meters in 1895-96, was 25,-428. The number of meters in Liverpool is not known, but in 1901, 28% of the total supply was metered, the metered services including, as stated, water sold for trade purposes, to ships and for workhouses and industrial schools. Probably there are not over two thousand meters in the city.

In considering the difference of 7.4 gallons per capita per day in the use of water in Berlin and Liverpool, even with a greater number of persons per service in Liverpool, we must keep in mind that Berlin is a great residence city, whereas Liverpool is a great

manufacturing city, and that the different occupations of the inhabitants easily account for the difference in the use of water. The large number of inhabitants per service in both of these towns is the real reason for the low use of water, since waste is greater in proportion to the number of services.

Manchester.—The population supplied at Manchester is stated at 1,100,000 with a daily consumption per capita of about 36 U. S. gallons. There are only 7,000 meters in use. The number of inhabitants per service is not given, but it is safe to say that it is large.

Birmingham.—The population supplied with water in Birmingham, is 800,000 and the daily consumption per capita is about 30 U. S. gallons. There are about 4,000 meters in use.

English Cities Generally.—The English cities generally do not favor metering—they are able to keep the use of water down to 30 to 50 U. S. gallons per capita per day by rigid inspection.

However, in comparing European cities with American, we must keep in mind the difference in conditions. In the German cities, the number of fixtures from which water can leak and waste is reduced to a minimum; the number of opportunities for losses from leaky joints, hydrants, valves, service pipes, etc., is reduced to a minimum; the difficulties of keeping close watch to prevent leakage and wastage are likewise reduced to a minimum. When it is understood that, excepting in the finer hotels and better class of apartments, permanent wash stands with hot and cold water, and wash tubs for laundry purposes supplied with hot and cold water, and such other fixtures as are common in our cities, are unknown in most of the European cities, it will be realized that the opportunities for wasting water are limited.

New York City.*—In New York, the consumption

*Fuertes, Waste of Water in New York and its Reduction by Meters and Inspection. A report to the Merchants Association. Pp. 30-31.

of water in 1900 was about 116 gallons per capita per day, but in 1904 it was stated at 135 gallons. In an estimate as to the cost of metering for a term of years, in comparison with the cost of constructing works to take care of the increase in use which it is assumed will inevitably occur, Mr. James H. Fuertes places the average population during a term of twelve years from 1906 to 1918, at 4,800,000 and the average number of inhabitants per service at 16, whence if every service were metered, there would be required in the City of New York, 300,000 meters. These he estimates at a cost of $2.36 per meter per year for meters, repairs, renewals, interest, reading, sending out bills, etc., but an examination of the meter statistics of Rochester, as per the accompanying table, shows that this estimate is low and since New York is an expensive place in everything else, we may be sure that the meters would cost considerably more than this, per year. Mr. Fuertes recognizes the fact that estimates will vary, in the statement, "There is a possibility of wide divergence between two independent estimates," but on the basis of an average number of 16 consumers per service and the average cost of meters of $2.36 per meter per year, he figures out for twelve years a saving of over $25,000,000. Suppose, however, that the ratio between number of consumers and number of services in New York was the same as at Rochester—that is, there were 5.2 consumers per service instead of 16—it would mean that 900,000 meters would be required to fully meter New York city for a population of 4,800,000 instead of 300,000 meters, and if we now compute the saving on this new basis, we shall find not only that there is no saving but that the meters are more expensive than to build additional works. This illustration is given merely to show that what is true in one place is not necessarily true in another and that in this matter of metering, as in everything else, each problem must be worked out on its own merits.

Large Variety of Meters Used One Difficulty.—

One difficulty about the meter business has been the disposition of cities to use a large variety of meters. The following list of cities, with number of different kinds of meters in use is given in order to emphasize this proposition:

Name of City	Number of kinds of meters in use	Name of City	Number of kinds of meters in use
Albany	16	Newton	17
Brockton	8	Philadelphia	14
Fall River	5	Rochester	14
Fitchburg	14	Toledo	11
Kansas City	14	Woonsocket	11
Lawrence	20	Yonkers	17
Lowell	18		

Number of Meters in Use in Comparison with Number Removed, Repaired and Reset in a Year.—The following tabulation shows the total number of meters in use in a few cities in the year 1905, together with the number removed ,repaired and reset during the year:

City	Year	Total number of meters	Number removed, repaired and reset	Per cent of total number
Albany	1905	2,799	555	20%
Kansas City	1905	11,344	1,704	15%
Lowell	1905	7,889	635	8%
Rochester	1905	14,065	1,197	9%
Total		36,097	4,091	11%

Relation Between Use of Water and Number of Consumers per Service.—It is not intended to write a long paper on the general subject of metering, but before closing I wish to request your special attention to the following tabulations showing the relation between the use of water and the number of consumers per service. The first of these gives a number of American cities, while the second gives a number of German cities:

AMERICAN CITIES.

Name of City.	Year referred to	Populat'n or number of consumers.	Number of services in use	Number of inhabitants or consumers per service.	Number of Meters	Daily use of Water per capita.
New York	1898	1,950,000	121,000	16.1	35,442	116.0
Fall River	1900	104,523	6,943	15.1	6,544	36.0
"	1890	69,000	4,980	13.9	3,717	31.0
"	1880	36,440	2,685	13.6	1,583	37.1
"	1905	105,070	7,744	13.5	7,523	42.0
Woonsocket	1905	32,196	2,776	11.6	2,366	32.0
Lawrence	1904	68,551	6,581	10.4	5,744	42.3
Hartford	1904–5	102,400*	10,006	10.2	9,860	62.0
Kansas City	1905	250,000	24,697	10.1	11,344	73.4
Yonkers	1905	61,707	6,265	9.8	6,207	77.0
Providence	1904	207,900	23,381	9.0	20,489	67.0
Lowell	1905	94,889	11,451	8.3	7,889	57.7
Brockton	1905	52,424	6,467	8.1	5,851	38.3
Chicago	1890	1,208,669	155,096	7.8	3 924	126.0
"	1900	2,007,695	308,945	6.5	6,396	160.6
"	1904	1,962,251	339,044	5.8	8,102	203.3
Cleveland	1904	455,000	60,627	7.5	30,226	138.0
Syracuse	1904	117,000	15,969	7.3	11,059	102.0
Covington	1904	45,318	6,243	7.3	5,441*	56.9
Springfield	1904	74 916	10,641	7.0	3,987	130.0
"	1903	54,000	10,471	5.2	3,798	216.0
Fitchburg	1905	33,000	4,745	7.0	3,068	93.0
Milwaukee	1900	285,315	41,483	6.9	28,386	83.0
"	1904	315,000	49,835	6.3	39,138	89.0
Madison	1903–4	21,000	3,462	6.1	3,336	71.0
Taunton	1904	27,500	4,873	5.6	2,199	64.0
Rochester	1905	181,670	34,243	5.3	14,065	85.7

GERMAN CITIES.

Berlin	1868	265,010	5,914	45.0	896	26.1
"	1880–1	883,555	15,750	56.0	16,350	16.6
"	1895–6	1,719,183	23,912	72.0	25,428	18.2
Bremen	1894–5	149,000	14,866	10.0	1,748	21.9
"	1899–0	167,000	19,487	8.6	2,662	25.7
Charlottenburg	1889	145,000	2,233	65.0	2,233	9.5
"	1896	350,000	8.161	42.9	7,997	16.1
Danzig	1888	100,787	4,059	24.8	3,845	27.4
"	1895	120,000	4,332	27.7	4,070	23.7
Dresden	1876	199,500	4,419	45.1	2,047	12.4
"	1898	366,000	10,407	35.0	7,904	26.7
Frankfort-on-Oder	1888	54,000	. 953	56.7	120	10.6
"	1895	59,049	1,210	48.8	186	14.3
Halle an der Saale	1888	86,802	4,136	21.0	1,314	25.1
"	1896	117,500	5,272	22.0	4,819	21.7

GERMAN CITIES—Concluded.

Name of City.	Year referred to	Populat'n or number of consumers.	Number of Services in use	Number of inhabitants or consumers per service.	Number of Meters	Daily use of Water per capita.
Hamburg	1890	568,700	18,100	31.4	4,814	54.0
"	1899	684,400	20,036	34.2	9,888	47.0
Hanover	1888–9	105,800	5,832	18.1	288	32.8
"	1895–6	246.000	8,894	27.0	8,894	21.2
Karlsruhe	1880	50,500	1,659	30.5	.....	20.8
"	1895	84,000	3,345	25.1	.....	37.0
"	1899	95,000	3,935	24.1	.....	32.0
Leipzig	1875	127,000	2,913	43.6	450	17.4
"	1885	170,300	4,061	41.9	896	20,3
"	1889	185,600	5,602	33.0	1,295	27.7
"	1891	362,600	6,884	52.7	6,186	15.3
"	1894	396,400	10,115	39.2	10,178	15.6
"	1898	422,000	12,342	34.2	12,856	17.7
Wuerzburg	1892	61,000	2,324	26.2	149	42,0
"	1897	71,000	3,045	23.3	350	56.6

*Approximate.

In considering the foregoing tabulations, perhaps the theory that the use of water is directly related to the number of consumers per service is most strikingly illustrated in Leipzig. In 1875, with 43.6 persons per service, the use of water was 17.4 gallons per capita per day, while in 1889, with 33.0 persons per service, the use was 27.7 gallons per capita per day. In the two years from 1889 to 1891, the population of the city almost doubled, with comparatively little increase in the number of services. Consequently, we find that in 1891 there were 52.7 persons per service, with a daily per capita use of water of but 15.3 gallons. In the next few years, the number of services was greatly increased, so that in 1898, there were very nearly twice as many services as in 1891, with only a small increase in population. In that year there were 34.2 persons per service, with a daily per capita use of water of 17.7 gallons. About 1890, there was a large increase in the number of meters in Leipzig, and in previous discussions the credit has all been given to

meters for the reduction in the use of water, from what it was in 1889.

Price of Metered Water to Manufacturers.—The price of metered water to manufacturers in Rochester is now 14c per thousand gallons, or what is the same thing, at the rate of $140 per million gallons. The following are the costs of furnishing water, as taken from the Annual Reports of the Department of Public Works for the years 1902, 1903 and 1904:

Year	Cost per million gallons figured on total maintenance.	Cost per million gallons figured on total maintenance plus interest
1902	$18.68	$76.86
1903	20.88	60.08
1904	26.30	66.32
Mean	$21.95	$67.75

The preceding figures show that water could be sold at $70 per million gallons, or 7c per thousand gallons, and the city still not lose any money

According to the 5th Annual Report of the Department of Public Works for 1904, the proportionate part of the consumption of water that is metered is 37%, whence the unmetered part is 63%. The following shows the amounts received from water rates in 1904:

Fixture rates	63%	$147,957.47
Metered rates	37%	277,137.21
Total	100%	425,094.68

Summary.—The following summary gives the main points of the foregoing paper in concise form:

(1). The meter department have considerably reduced their running expenses in the last few years.

(2). Statistics in the annual reports not only show that meters do not necessarily reduce the use of water, but in some cases they show the contrary—this is markedly true of the figures in the 19th Annual Report of the Executive Board.

(3). The cost of removing, repairing and resetting meters is as an average for fourteen years, $4.80 per meter in Rochester, while there have been 10,883 meters removed and reset during the period.

(4). The cost of setting and testing new meters is as an average for fourteen years, $3.24 per meter in Rochester, while there have been set during the period 11,497 new meters.

(5). The cost of general expense of maintenance of meters is as an average for fourteen years, $0.37 per meter per year in Rochester.

(6). A meter has to be removed and repaired about once in from twelve to fifteen years and the total life of a meter is taken at about twenty years.

(7). A study of the standard meter curve shows that the use of water in Rochester is about as low as it is likely to be, although by metering 100% of the services, the use may be reduced to 65 gallons per capita per day.

(8). At Providence the population supplied with water in 1904 was 207,900, while at Rochester it was 175,000. Total number of services in use in Providence was 23,381 and in Rochester 33,170. Total number of meters in Providence was 20,489 and in Rochester, 12,260. The use of water in Providence in 1904 was 67 gallons per capita per day, while in Rochester the use of Hemlock Lake water was 75.5 gallons per capita per day, which was a decrease of 4.5 gallons over 1903. The increase for the same year at Providence was 2 gallons per capita per day. Hence, there are other reasons for the increase or decrease in use of water besides the use of meters.

(9). In searching for the chief reason, we find that the ratio of inhabitants to number of services in 1904 in Providence was 9.0 and in Rochester 5.2—that is, there were in 1904, 9.0 persons per service in Providence and in Rochester only 5.2 persons per service. Thus far it has been overlooked that the relation between inhabitants and number of services is an important consideration in the water business.

(10). In Berlin, there is an average of over seventy persons to each service pipe and the daily use of water is only about 20 gallons per capita. The opportunities for waste and leakage are over thirteen times as great in Rochester as in Berlin.

(11). In Liverpool, with a density of population of 125 per acre, the use of water in 1901 was 37 U. S. gallons per capita per day. The number of inhabitants per services is about seventy-five. There are comparatively few meters used.

(12). In Manchester with but 7.000 meters the daily use of water is about 36 U. S. gallons per capita per day.

(13). The English cities generally do not favor metering.

(14). The number of kinds of meters used in the various cities of this country is large—it would be better to use only one or two kinds in a town.

(15). Other conditions being equal, there will be less water used per capita per day in a town with a large number of consumers per service than in a town with a small number of consumers per service.

(16). The cost of supplying water in Rochester, including the total maintenance account, is $67.75 per million gallons, while the meter rate for selling water is $140 per million gallons.

(17). The proportionate part of the consumption of water that is metered in Rochester is 37%, whence the unmetered part is 63%.

(18). The fixture rates in 1904 paid $147,957.47, while the metered rates, or 37% of the total, paid $277,-137.21. This shows an inequality and injustice between the fixture rates and the metered rates which should be corrected. Had the fixture rates yielded at the same rates as the meters, they would have produced $471,882.28, and the total income of the water works, instead of being $425,094.68, would have been $749,019,49.

(19). Those water takers who pay meter rates pay 100% profit, while those who take water at flat rates, receive it at far less than cost.

STATISTICS OF METER DEPARTMENT AT ROCHESTER, NEW YORK, 1886-1905, INCLUSIVE. a

Fiscal Year: Day of month ending	Fiscal Year: Year	Number of meters in use at end of year	Cost of new meters and meter parts	Amounts received from consumers for sale and repairs to meters as well as sale of junk, etc.	Proportionate part of barn account, chief engineer's office, superintendent, etc, chargeable to meters	Total expenditure chargeable to meter department each year	Total expenditure of meter department less amounts received from consumers, all refunds, etc.	Number of services in use in city at end of fiscal year	Per cent of services metered	Approximate population	Increase in number of meters during year	Increase in number of services during year	Daily use of Water per capita Gallons: From Hemlock lake domestic system	Daily use of Water per capita Gallons: From Holly direct Pressure system	Daily use of Water per capita Gallons: Total of both systems	Gross expense to city for each meter Col. 17 ÷ Col. (3)	Net expense to city for each meter Col. (18) ÷ Col. (3)	Year
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Apl. 5	1886	978	$ 1,552.45	$ 662.76	$ 482.79	$ 5,935.64	$ 5,272.88	15,810	6 2	111,630	89	1,480	46 0	10.8	56 8	$6.07	$5.39	1886
4	1887	1.094	2,582.97	1,144.47	525.45	6,993.74	5,849 27	17,454	6.3	116,080	116	1,644	49.8	11 7	61.5	6.39	5.35	1887
2	1888	1,400 b	9,648.65	867.38	547.45	15,620.68	14,753.30	19,407	8 0	120,540	306 b	1,953	49.6	12.1	61.7	11.16	10.54	1888
1	1889	1,700 b	5,668 50	1,233.40	719.79	11 748.91	10,515.51	21,358	8.0	124,990	300 b	1,951	49.5	12.5	62.0	6.91	6 18	1889
7	1890	2,115	8,912.88	1,322.00	747.73	16,265.58	14,943.58	23,000c	9.2	129,440	415	1.642c	49.3	12.9	62.2	7 69	7.07	1890
6	1891	2,844	14,540.88	5,518.62	3,442 73d	27,968.04	22 449.42	24,864	11 4	133.896	729	1,864c	49 3	13.4	62.7	9 83	7.89	1891
4	1892	3,163	4,918.18	3,373.33	1,065.98	17.311 97	13,938.64	25.224	12.5	139,365	319	360	48.9	12.6	61.5	5.47	4.41	1892
3	1893	3,460	10,241.07	2,988.00	1,595.43	23,627.81	20,639.81	26,167	13.2	144,800	297	943	48.3	11.5	59.8	6.83	5.96	1893
2	1894e	3,724	21,157.37	3,481.76	1,537.40	34,983.77	31,502.01	26,908	13.8	147,000	264	741	50.8	12.2	63.0	9 39	8.46	1894e
1	1895	4,043	1,181.16	3,450.89	1,121.26	15.528.42	12,077.53	27,410	14.7	149,200	319	502	50.1	11.9	62.0	3.84	2 71	1895
Dec. 31	1895f	5,157	5,245.55	9,686.32	1.280.31	17,667.93	7,981.61	28,420	18 2	151,400	1,114	1,010	64 8	12.9	77.7	4.56g	2.05g	1895f
	1896	6,005	9,048.33	7,564 81	1,292.80	27,602 63	20,037.82	28,900	20.8	153.600	848	480	66 7	11.1	77.8	4.60	3.34	1896
	1897	6,497	6,614.03	5,839.14	1,224.54	24,362.69	18,523.55	29,433	22 1	155,800	492	533	69.1	9.2	78 3	3.75	2 85	1897
	1898	7,227	6,264.62	8.373.14	991.51	21,677.24	13.304.10	29,851	24.2	158,000	730	418	70.4	8.7	79 1	3.00	1.84	1898
	1899	7,994	8,334.15	10,233.79	1,203.97	25.367 52	15,133.73	30,269	26.4	160,200	767	418	75.0	8.1	83.1	3 17	1.89	1899
	1900	8,752	8.673 17	9,713.68	1,249.93	25,252.57	15,538 89	30,681	28.5	162,608	758	412	76.3	8 8	85.1	2.89	1.78	1900
	1901	9,435	5,759.39	8,614.63	1,146.60	23.241.24	14,626 61	31,146	30.0	165.000	683	465	80 1	9 8	89.9	2.46	1.55	1901
	1902	10,310	7,858.42	10,794 81	1,188.24	23,203.70	12,408.89	31,894	32.3	168,000	875	748	81.2	12.7	93.9	2.25	1.20	1902
	1903	11,201	7,105.78	12,339 37	1,365.79h	23,808.48	11,469.11	32,381	34.6	171,000	891	487	80.0	10.0	90.0	2.13	1.02	1903
	1904	12,260	11,090.46	13,079.41	1,381.44	29,145.67	16,066.26	33,170	36.9	175,000	1,059	789	75.5	8.6	87.1	2.38	1.31	1904
	1905	14,065	22,332.91c	20,666.00 c	1,381.44j	43,790.19c	23,124.19c	34,243	41.1	181,670	1,805	1,073	78 4	7.3	85.7	3.11c	1.64c	1905
Total or mean			$178,730.92	$ 140,947.71	$25,492.58	$461,104.42	$320,156 71									$5.14	$4.02	

a A few small items are not included herein.
b There is a discrepancy in the figures for these two years as given in annual reports.
c Approximate.
d New barn built during this year at total expense of $26,656
e New conduit from Hemlock lake in service in October, 1894.
f A short fiscal year here.
g The gross expense per meter for the short fiscal year of nine months was $3.42 and the net expense $1,54; $4.56 and $2.05 are on the same basis for twelve months.
h Includes charge for fire alarm telegraph horses in 1902. Taken same as for 1904.

WATER CONSUMPTION, WASTE AND METER RATES.

James L. Tighe.

The questions which I propose to discuss before this association, namely, water consumption, waste and meter rates, are not new ones. They have been discussed over and over again for years past by water works men both privately and in association meetings. Likewise the literature on these subjects is considerable, and still, notwithstanding, I think it will have to be admitted that the practical results, that might be expected, have not been realized.

This statement may be a rather broad one and more or less questionable. Let us investigate it then and see if it is not substantially a correct one.

There are no questions probably in water supply, with the exception of quality alone, of more importance than the consumption and waste of water, yet, what advancement has been made upon scientific or systematic lines, to keep both under proper control.

With the one exception of possibly knowing the total consumption, which in many cases, is only indifferently approximated or guessed at, how much does the management of the average public water supply know about the various ways in which water is used and wasted?

For instance, how many know, even approximately, how much of the total quantity of water daily furnished reaches the consumer, or how much is lost on its way in leakage through the street mains and service pipes; how much is furnished in what may be termed the day and night periods; how much is used for domestic purposes proper; how much for industrial establishments; how much for all public purposes, differentiated, as to where it is used, whether in public buildings, street sprinkling, drinking fountains, etc., and last but not least, how much is known about the various causes and conditions which lead to waste and the best methods for restricting the same, especially where the water is not sold by measurement.

Must it not be admitted that comparatively little is known about these things, and if such is the case, the statement made above, is true, so far, at least, as consumption and waste are concerned.

Of course it can be argued that, when water is sold to the taker by measurement the greater portion of this data will then be known.

However, admitting this, are we justified in waiting until then. Certainly not, for that day, unfortunately, is rather far off as yet from many towns and cities, notwithstanding how near it may be to others. At all events the way to bring it still nearer to all, is to obtain by the best means at our command such knowledge in detail about these things as will enable us to educate and convince the public, who, sooner or later, will see the wisdom and force of our arguments.

This is exactly what the City of Holyoke has been doing for some years, and with what success I shall let you infer from the facts as here stated, believing, that the presentation of such, will be of more interest to you than any discussion by me upon the general questions themselves.

The City of Holyoke is situated in the State of Massachusetts on the west bank of the Connecticut River, about 80 miles above its mouth. It is a comparatively young city increasing in population from 5648 in 1865 to 51,000 at the present time, and is noted for its water power and paper industry.

The latter is the largest in any one town or city in the world, having an output of 350 tons of paper per day, while the former was also the largest in the world, until, the development of the Niagara power in 1892.

Holyoke is in every sense a modern up to date city, owning its own sewerage system, water supply and lighting plant.

The latter, although, but a few years taken over from a private corporation at an enormous cost and after four years of litigation, is already a great municipal success.

But, it is not its great water power or its great paper industry or its successful municipal lighting plant that should make Holyoke more or less notable among

other cities large or small throughout the country. No; it is because of one or two special features that it has, and to which, so far as the writer knows, no other city throughout the country can lay claim.

One of these features is, its very extensive sewerage system which is connected with every dwelling, with the exception of thirty, within the city and suburban limits, and with every dwelling, with the exception of seventy-seven, within the boundary lines of the whole territory of the city which covers an area of 16 1-2 square miles.

This you will admit is an unique record, and one, it is believed, that cannot be surpassed or even equalled by any city or town not only on this continent but throughout the whole world.

The other special feature of the city, is also an unique one, and relates to the water department, which, besides, not only takes care of its own indebtedness and maintenance, but pays a tax to the city proper each year, in the same manner, exactly, as if it were a private corporation. This tax is no book keeping arrangement either, but is levied by the assessors and paid over to the city proper in hard cash each year by the water department, in accordance with a special act of the Legislature passed in 1901.

For some years prior to this time, some of the intellects of municipal economics had debated, over and over again, municipal equity in support of municipal government, out of which naturally arose discussions upon the status of the Water Department towards the support of the Municipality.

In these discussions the advocates of the Water Department argued, that the cost of supplying water for municipal purposes and hydrant service for fire protection, should not be borne by the water taker but by the tax-payer. On the other hand the advocates on the opposite side argued that the Water Department had police protection, the credit of the city and valuable franchises, &c., all of which were free grants from the taxpayer.

These arguments, which were apparently sound on both sides, and which probably could be applied in common to most cities having municipal water supplies, were finally

settled by the Legislature, which, enacted the following law on a petition from the Mayor and Board of Water Commr's of the city, who had mutually agreed upon the draft of the bill beforehand.

ACTS AND RESOLVES, MASSACHUSETTS, 1901.
(Chapter 319.)

An Act relative to the water department of the city of Holyoke.

Be it enacted, etc., as follows:

Section 1. The Water Commissioners of the City of Holyoke, etc.,

Section 2. The said Board of Water Commissioners is hereby authorized and directed to pay over to the Commission of the sinking fund of the said city in each year, on or before the first day of October, from its net earnings, a percentage upon the total cost of the construction of the said water works, as estimated in the annual reports of the said Water Commissioners, which shall be the same as the percentage of taxation established for city, county and state taxes in the City of Holyoke in that year; and the said commissioners of the sinking fund are hereby authorized to collect the said sum. In case the net earnings do not equal the said percentage the whole net earnings shall be paid over as aforesaid. The amounts so paid or collected shall be used toward the payment of municipal bonds other than water bonds.

Section 3. The Board of Water Commissioners is hereby authorized and directed to collect payment from all municipal departments of the city of Holyoke, except the Fire Department, for the water used by them at the same rate which is paid by other consumers.

Section 4. The Board of Water Commissioners is also hereby authorized and directed to collect from the Fire Department an annual rental, not exceeding eight dollars for each public hydrant. The rental shall include the cost of all water used by the Fire Department for fire or other purposes, including the cost of furnishing and maintaining the hydrants.

It is seen by this bill, among other things, such as the Municipality paying for the water used by it and for hydrant service, that the valuation of the water works is not fixed by the Assessors but by the construction account shown by the Water Commissioners in their annual report of the previous year.

The reason for making this provision, was, upon the principle that the tax to be collected should be known as far ahead as possible, so as to enable the Water Board to govern its expenditures accordingly. It was also made in order to prevent the city arbitrarily increasing at any time the valuation of the works, a provision which was perhaps unwarranted, yet, who can tell what even City Govern-

ments might be tempted to do, especially, in times when large deficits have to be met. *

The law has now been in force for five years and has given such excellent satisfaction that similar laws governing the municipal water supplies of other cities can be highly recommended.

In 1895 it was thought that the water supply of Holyoke was becoming inadequate and a new supply on the writer's suggestion and recommendations was secured and put into commission within three years after.

At this time the consumption of water in the city was estimated to be 85 gallons per capita per day, which, from actual measurements that were made of the consumption then, showed these figures to be correct.

The new supply, if fully developed was estimated to be sufficient for a population of 150,000 using a hundred gallons per capita per day.

Since it would be many years before the requirements of such a population would have to be met, it was considered advisable to develop only part of the new supply at first. Accordingly, this is what was done, and the new supply was developed to meet only the requirements of the city for 15 years on a 100 gallons per day per capita basis, with allowance for increase in population, when afterwards storage reservoirs could be built from time to time as required, until the full development was reached.

It seemed as if this new supply was the impetus for the greatest extravagance in the use of water; but this could not be satisfactorily shown, since, there were no ready means of measuring the actual consumption.

Things went along, however, until 1903, or five years after the advent of the new supply, when the writer thought it was high time to make some effort to know, even approximately, the facts in the matter, and with his own staff of assistants made some measurements with pressure gauges of the flow in the large pipes leading from the reservoirs to the city.

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*For a full discussion on the economics of this question see paper by author in Journal N. E. W. Works Asso., page 352, vol. 18, year 1904.

These measurements were continued night and day for a week and resulted in showing an average consumption of 142 gallons per capita per day.

This result was so interesting that it led to the introduction, within the following year, of 4 large meters (two Venturi and two Premier meters) to measure the output from the reservoirs to the city.

When the new meters were installed, they not only fully substantiated the large consumption shown by the measurements made by the Engineering Department, but went somewhat farther by showing a consumption per capita of 156 gallons per day or a consumption which had increased per capita to nearly double itself in about eight years.

During these years what did the records of the water department show? They showed the consumption to be as follows:

In 1897	85.33	Gallons per capita per day
In 1898	85.79	Gallons per capita per day
In 1899	95.42	Gallons per capita per day
In 1900	102.84	Gallons per capita per day
In 1901	102.87	Gallons per capita per day
In 1902	102.00	Gallons per capita per day
In 1903	102.77	Gallons per capita per day

This table is evidence, in itself, sufficient to show what reliance should be placed upon records of consumption, if, not knowing exactly how those records are compiled.

No doubt, had the large meters not been installed, the records of the consumption in 1904, and since, and probably for many years to come, would not show a much higher consumption than in those years previous to 1904.

After the large meters which were installed near the end of 1904, had shown the consumption to be between 150 and 160 gallons per capita per day, a more vigilant inspection, with additional inspectors, was inaugurated at once. This inspection resulted in cutting down the consumption, so as to average for the year 1905, 116 gallons per capita per day.

This reduction was very encouraging, and it was expected that the following year, 1906, would see the average consumption reduced to a hundred gallons or less per day per capita.

Such expectations however, were not fulfllled, as the average consumption for 1906 was 114 gallons per day per capita or only 2 gallons less per capita than in 1905. This result has been the more disappointing since a most vigilant inspection was enforced, even to the shutting off of the water from premises where leaky fixtures were not promptly repaired on notification from the Department.

It has also been disappointing to think that the consumption cannot be reduced to within 32 or 33 gallons per capita of what it was ten years ago, when practically the same conditions existed, except, that the population has increased about 10,000 since then.

This demonstrates again what has been repeatedly demonstrated before, how unwise it is to allow water consumers to become extravagant in the use of water, no matter how abundant the supply may be, for, if ever necessary afterwards to curb this extravagance and keep the consumption within reasonable limits, the task will be a difficult one and will take more than one or two years to perform.

While pointing out that the present consumption, per capita in this city, cannot be reduced under vigilant inspection, to what it was ten years ago, it would not be fair to conclude that the difference in consumption per capita between then and now is all waste, as it can hardly be denied that the use of water for all legitimate purposes has greatly increased within the last ten years, even in cities that have been wholly metered.

This has been demonstrated quite recently by Mr. William S. Johnson, assistant engineer of the State Board of Health of Massachusetts, in a paper read before a meeting of the New England Water Works Association in March last.

The following diagram shows the total consumption of water per capita in Holyoke in 1906, twenty-eight per cent. of which, or 32 gallons per capita had passed through 318 meters installed in industrial establishments, municipal

buildings, &c., saloons, hotels, laundries, livery stables, &c., while the remainder or 82 gallons per day per capita, with the exception of what was lost in leakage through service pipes and in 83 miles of street mains, passed through 3563 unmetered services connecting 10,943 closets and urinals, 5103 bathtubs and served 10,740 families.

DIAGRAM SHOWING COMSUMPTION OF WATER.

Of this total quantity there was used

In paper mills	11.29	gallons	per day	per capita
In thread mills	1.58	gallons	per day	per capita
In cotton mills	0.19	gallons	per day	per capita
In woolen mills	1.15	gallons	per day	per capita
In silk mills	0.70	gallons	per day	per capita
In wire mills	0.11	gallons	per day	per capita
In lumber mills	0.21	gallons	per day	per capita
In machine shops	.73	gallons	per day	per capita
In steam boiler shops	0.06	gallons	per day	per capita
In elevators	1.21	gallons	per day	per capita
In laundries	0.43	gallons	per day	per capita
In livery stables	0.29	gallons	per day	per capita
In saloons	1.80	gallons	per day	per capita
In hotels	1.59	gallons	per day	per capita
In hospitals	0.53	gallons	per day	per capita
In churches	0.24	gallons	per day	per capita
In society & club rooms	0.42	gallons	per day	per capita
In miscellaneous	1.55	gallons	per day	per capita

In Municipality

In Drinking Fountains	2.68	gallons	per day	per capita
In Street sprinkling	2.07	gallons	per day	per capita
In Schools	1.87	gallons	per day	per capita
In Bath houses	0.42	gallons	per day	per capita
In Lighting dept.	0.42	gallons	per day	per capita
In Alms house	0.29	gallons	per day	per capita
In Engine houses	0.17	gallons	per day	per capita
In City hall	0.12	gallons	per day	per capita

It can be seen by the above table that the water used for all municipal purposes, except that used for fire service, was 8.04 gallons per day per capita. Of this drinking fountains, street sprinkling and public schools used 83 per cent.

DIAGRAM SHOWING METERED WATER USED IN FACTORIES AND BY MUNICIPALITY IN YEAR 1906 IN HOLYOKE, MASS.

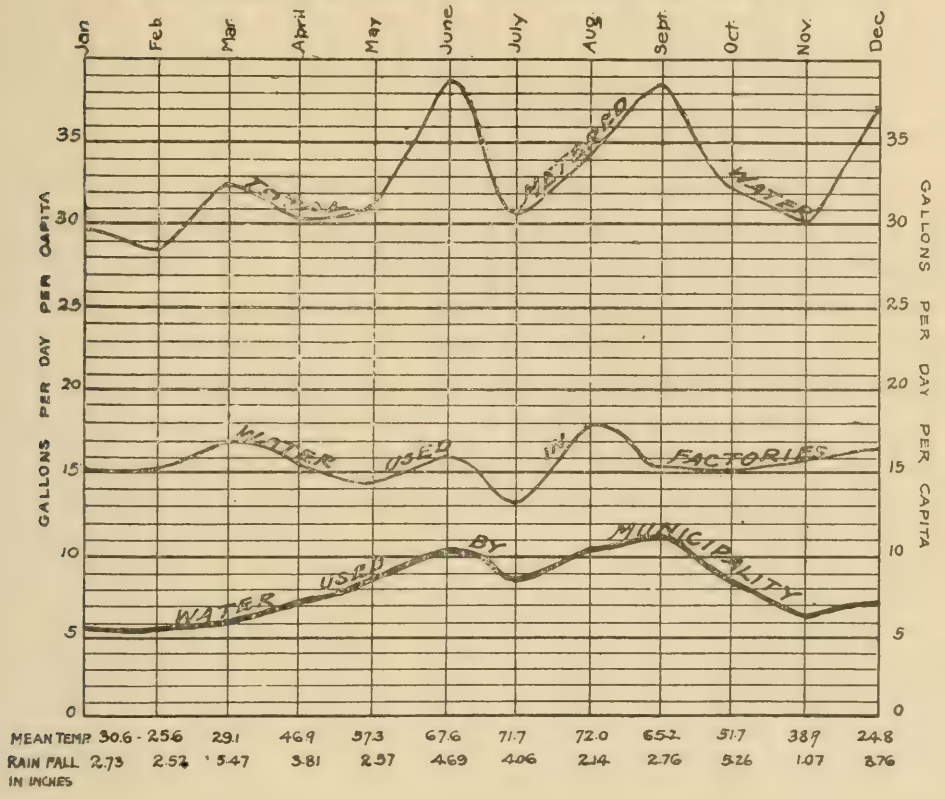
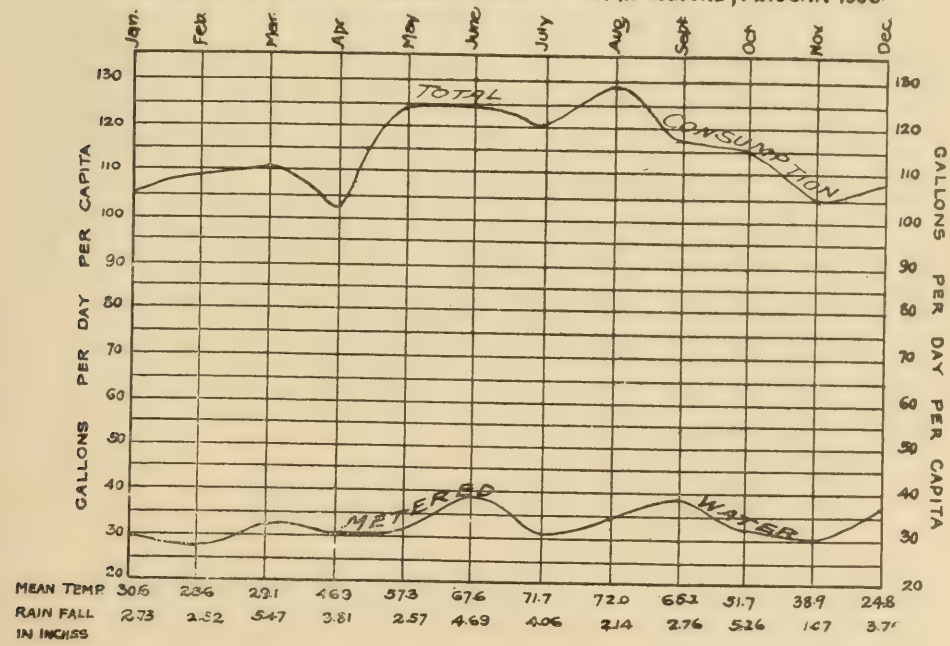


DIAGRAM SHOWING CONSUMPTION OF WATER IN HOLYOKE, MASS. IN 1906.



or 6.67 gallons per day per capita. The quantity used in the latter, namely, 1.87 gallons per day per capita, was equivalent to 26 gallons per school day per pupil and teacher, a quantity which must be considered high if compared with the consumption in some of the other public schools throughout the country.

The explanation for this high consumption may be in the fact, that the sanitary equipment of our schools is most modern, and not only includes automatic closets but bubbling fountains, which are kept in continual use during school hours. The germ theory, let it be noted, has so far advanced in Holyoke that the old drinking tin cup is a thing of the past. It will also be observed in the above table that the water used in manufacturing concerns, namely; paper, woollen, cotton, thread, silk, and wire mills was 15.02 gallons per capita per day, of which 11.29 gallons was used in the paper mills alone.

Your attention is called to this fact, because, in many cities manufacturing concerns have their own water supplies; consequently, when comparing the statistics of consumption of different communities, such should be taken into consideration, if anything like true comparisons are to be made.

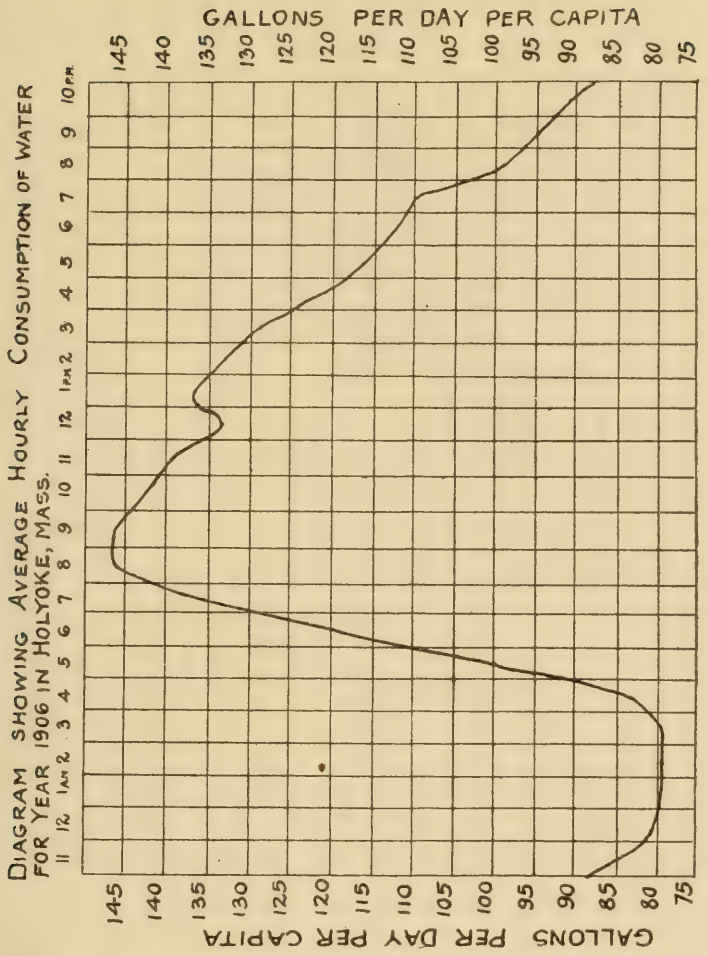
The following diagram shows the water consumed per capita per day by the municipality in 1906 and also that consumed by the manufacturing concerns.

This hourly record is perhaps more easily seen and compared in the following diagram.

This is seen in the following table which shows the hourly consumption per capita of the average day of the average week in 1906, and which, except in the figures, is a fac-simile of the hourly records of the average day of each week as computed from the returns of the large meters each week.

HOLYOKE WATER WORKS.

Record of water consumption in City of Holyoke as measured by large meters for average day in week ending 11 P. M.


GALLONS PER DAY PER CAPITA
145 140 135 130 125 120 115 110 105 100 95 90 85 80 75
DIAGRAM SHOWING AVERAGE HOURLY CONSUMPTION OF WATER FOR YEAR 1906 IN HOLYOKE, MASS.
11 12 1AM 2 3 4 5 6 7 8 9 10 11 12 1PM 2 3 4 5 6 7 8 9 10PM
145 140 135 130 125 120 115 110 105 100 95 90 85 80 75
GALLONS PER DAY PER CAPITA

Estimated number of water takers supplied, 51,000.

Hour	Gals. per cap. per day.
11 to 12 P. M.	85
12 to 1 A. M.	81
1 to 2	79
2 to 3	79
3 to 4	79
4 to 5	83
5 to 6	100
6 to 7	120
7 to 8	136
8 to 9	147
9 to 10	147
6 to 7	120

Hour	Gals. per cap. per day
7 to 8	136
8 to 9	147
9 to 10	147
10 to 11	143
11 to 12 M.	139
12 to 1 P. M.	133
1 to 2	137
2 to 3	133
3 to 4	128
4 to 5	121
5 to 6	117
6 to 7	113
7 to 8	110
8 to 9	98
9 to 10	95
10 to 11	91

Average for 24 Hours	114
Average 11 P. M.—5 A. M.	81
Average 5 A. M.—11 P. M.	123

Rate of night flow, 11 P. M. to 5 A. M., is 66 per cent. of rate of day flow, 5 A. M. to 11 P. M.

TEMPERATURE.

Maximum 57.8 Minimum 38.4 Mean 48.1

Rainfall for week.....inches

J. L. TIGHE, *Engineer.*

In order to know the night consumption, outside of what passed through the meters, a measurment was made of the metered consumption by reading the meters at 5 a. m. and 11 p. m., or as near these hours as possible for a period of one week.

These readings showed the consumption to be 14 gallons per capita, which, if deducted from 81 gallons would show a cosumption for domestic purposes at the rate of 67 gallons per capita per 24 hours.

This high consumption during the night period, in a

small city where practically every resident is in bed before midnight and where the fixtures are reasonably well looked after by a vigilant inspection, indicates that there must be a heavy leakage in the mains and service pipes, and thus, suggests, more or less, the findings of Mr. Dexter Brackett of Boston, who showed, in his report to the Commissioners of the Metropolitan Water Supply of Massachusetts in February 1904, that the average leakage in the mains and service pipes in Boston and the surrounding towns and cities within the Metropolitan district, was from 16½ to 25 gallons per capita per day.

Whether the leakage in the mains, which are all cast iron, and service pipes in Holyoke, of which none are older than 35 years, would show this high leakage as found by Mr. Brackett, can be ascertained, only, when the meter system is extended to the whole city.

Before leaving these questions of consumption and waste, it may be interesting to state that the consumption in the public schools in Holyoke, before the city proper had to pay for the water used, was, as found by test meters, 57 gallons per pupil and teacher per school day. This led to appeal after appeal from the Board of Water Commissioners to the Board of Public Works, who has charge of the schools, to cut down the waste, but all was in vain, until after the passage of the act in 1901, compelling the municipality to pay for all the water used; when the consumption was cut down to about one half, as above stated.

In the same manner, when the saloons of the city were paying for water at fixture rates, test meters showed a consumption on the average of one and one half times as much as was afterwards shown in the same places under the meter system.

These illustrations, only show, what has been well known to all water works men, that, while consumption and waste can be controlled to a certain extent by vigilant inspection, it is best controlled by the meter, which, figuratively speaking, makes each water taker an inspector.

METER RATES.

Of all the questions relating to water supply, it seems

the question of meter rates has been the most neglected. Let the management of the average water supply be asked upon what grounds were the rates for metered water established in its town or city and what answer will be received?

Will the answer be, because these rates were based upon equitable and economic principles consistent with the requirements of the Water Works Department. Not at all; the answer will be, because the rates in other cities were investigated and lists of the same procured from which an average or something like an average rate was struck and fixed upon, irrespective entirely, of whether it was equitable or not to the water taker or to the Department

This is the method that has been usually followed, in at least nine cases out of ten, when establishing meter rates. And what other might be expected, since the meter rate, is only a degenerate offspring of a degenerate parentage, the fixture rate.

While some apology might be offered for the methods followed in establishing fixture rates, which had generally been established when little if any scientific methods were being applied to any phase of the public water supply, no such apology can be offered for the present method of establishing meter rates, since, the general introduction of meters is, with little exception, of modern date.

It is strange to think what little attention has been paid by the profession to such an important question, especially, when it is considered what scientific knowledge has been applied to some of the other phases of water supply within the last fifteen years.

The water works official or expert of to-day, if requested by a city to prepare a rate for metered water, based upon economic and equitable principles, what literature could he refer to that would aid him in the work?

The only literature in this line of any account, that the writer at least is acquainted with, is given in the journal of the New England Water Works Association, Vol. (19) 1905, in a report from a committee on meter rates of which the late Freeman C. Coffin of Boston, Mass., was chairman.

To establish equitable rates for metered water in a town

or city, immediately after the supply has been constructed and before fixture rates have been established, might not be so difficult a task, but to establish equitable meter rates in a town or city to supersede fixture rates of long standing, is another problem entirely, and one certainly sufficiently abstruse to perplex the most profound economist.

And yet, this is what the management of the water supply of Holyoke has under consideration at the present time.

In Holyoke, like in many towns and cities, the rate established at first for metered water was a sliding scale rate which was fixed, of course, in the usual way as pointed out above.

This scale had three prices, namely, fifteen cents per 1000 gallons, for the first fifty thousand gallons or less consumed per month; ten cents per one thousand gallons for the next 150,000 gallons or less consumed per month and 5 cents per 1000 gallons for all water consumed above 200,000 gallons per month with a 20 per cent. discount off each, for prompt payment.

About two years ago, owing to the appeals made by the small takers of metered water, the highest rate was abolished. This concession of the management was not satisfactory however, as the question was still agitated until a new flat rate of 5 2-3 cents per 1000 gallons was established with a discount off of 10 per cent. for prompt payment, thus making a net rate of 5 1-10 cents per 1000 gallons.

In the establishing of this new rate no revenue was lost to the department, as the loss and gain were equalized between the small and large taker, the former paying less and the latter more for water used. In other words the burden, if it might be termed so, was placed on those best able to carry it, which is considered a sound principle of economics.

At first some of the large takers threatened to install waters supplies of their own, but this spirit died out in a short time and the flat rate is in vogue ever since and has given entire satisfaction.

No sooner, however, were the demands of the small taker of metered water satisfied by the establishment of a flat rate, than, the student of Municipal economics, desired

to know why the same privilege of purchasing water by measurement would not be extended to the taker of water for domestic purposes, who, under the rules of the Water Department, had to pay for water at fixture charges. His argument being that the taker of water for domestic purposes was the real patron and main support of the public water supply for whose benefit it was constructed, and that, therefore, if any preference were to be shown to any one class of takers more than another, he should be the first to be considered.

The management saw that there was some force in this argument, and consequently decided that it should try and establish an equitable meter rate for all water takers alike who desired to use meters. In order, however, that no mistake might be made in this important undertaking, it was thought advisable to first install one hundred test meters in different classes and kinds of dwellings all over the city, so that from their returns some idea could be formed of what the consumption would be, provided, each water taker used a meter. Accordingly these meters were installed in the early part of the year, to be operated for twelve months, when at the end of this period the data secured will aid greatly it is thought in forming a basis for the new rate.

This new rate, it is needless to say, is, not only to be an equitable one for all water takers, but, also be such, that the revenue collected therewith, will meet all the requirements of the Water Works Department.

DISCUSSION.

MR. BEEKMAN C. LITTLE: The cost of meters at Rochester, N. Y. is a question which is of course of especial importance only to the tax payers of that city. Some of the statements made and conclusions arrived at by the author of the paper, with this title however, are so at variance with both the theories and practice of most Water Works managers that it seems proper to take up some of your time in an examination of a few of these points, to the end that a totally different and a much more correct impression of the meter situation in Rochester may be left, than would result by a mere casual reading of the paper in question.

I have been connected with the Rochester Water Works sixteen years and since October 1902 have had the honor of being Superintendent of this plant, and one of its several departments that I take especial pride in is the Meter Department. The progress of meter setting in the past two years has been very gratifying and the results already obtained, as well as those of which present indications give promise when we are entirely metered, are extremely satisfactory. It would not be fair then to the people of Rochester and perhaps not just to other Water Works authorities who may be considering the question of metering and need encouragement rather than discouragement, to allow the conclusions of the author of this paper to go unchallenged.

On the second page of the paper under discussion is the emphatic statement "It does not follow that the use of meters in Rochester will reduce the use of water." This statement is misleading, or at least ambiguous, and if the author means that the use of meters in Rochester will not reduce the leakage and wastage of water, the statement cannot be borne out by any facts. He states that in 1893 slightly more water was used per meter through metered services than was used per meter through metered services the year before. This may be so and may properly be a thing to be desired. In Rochester we are progressing; our families are growing, our houses are getting larger; we have more bath tubs and closets; our shops, and pos-

sibly our saloons, are doing more business and our factories are increasing their output. This means prosperity and no one wants to reduce from year to year the legitimate use of water such as is represented very generally by a metered service. It is not the comparison of metered services with metered services that tells the story, but it is the consumption through metered services compared with the consumption through unmetered or flat rate services that is interesting. It is not the use of water, but its abuse, that we are trying to check. Later on the author does compare the metered consumption with the flat rate consumption and states that in 1892 and 1893 the per capita consumption per day through the then metered services was actually more than the average per capita per day consumption figured for the entire city, (the greater part of the services at that time being unmetered). He reaches this conclusion by wrong deductions, as follows: 'In a certain year in Rochester there were 153,600 inhabitants and 28,900 services which makes an average of 5.3 people to each service, therefore the 1093 metered services furnished water to 5.3 times this number of people, and then the consumption, per capita was figured easily. Now, in 1893 only a very small proportion of the water was metered, as in general the plan was to meter only the larger consumers. These 1093 domestic metered services (only 4% of the total services in use), were then principally large consumers, such as boarding houses, apartment houses, flats, etc., in which the average number of inhabitants greatly exceeded 5.3 which was the average *based on the entire number of services.* Mr. Emil Kuichling, at that time Chief Engineer, of the Rochester Water Works, in one of the annual reports, quoted by the author, estimated that ten inhabitants to each of these services would be a conservative average. Taking this much more probable and logical average, the per capita consumption per day through these services becomes 24 gallons instead of 63 gallons and the conclusion reached by the author is found to be directly opposed to the facts. Using Mr. Kuichling's average for the 1896 records gives a per capita consumption of 53.4 gallons per day instead of the author's 100.8 gallons. It is proper to add that the small

consumption in 1892 and 1893 was due to the fact that it was necessary to practice rigid economy with our water as our new additional supply was not completed until 1894. This economy was effected by a pressure reduction system based on the closing down of certain valves at certain hours of the day, so that during these hours the legitimate use, as well as the wastage and leakage, was very materially checked.

As regards the author's figures on the cost of repairs of old meters and cost of setting of new meters, etc., I wish to make this explanation: The general metering of all our water services was only started in a systematic way in 1905; before that time a comparatively small percentage of our services were metered and each year saw only a small number of meters added, compared to the number we are now installing. The consequence was that the cost per meter, both for setting and maintenance, was much greater for this desultory and half-hearted meter plan than now obtains when we have a much larger number of meters to work over and install and when a much more systematic force can be employed. While the author concedes in his paper that the expenses of running the Meter Department have been considerably reduced in the last few years, he nevertheless takes the average of the fourteen years ending in 1904 in estimating the probable cost of repairs, maintenance and the setting of new meters. For instance, the author gives the average cost per meter for setting 12,260 meters, (the number in use in 1904,) as over $3.24. Figuring by exactly similar methods as is used in this table of the author's, the cost of 1782 meters set in 1905 was $1.50 per meter and the 5563 set in 1906 cost only 88cts., per meter to install. In 1907 we expect to set approximately 6000 meters and the cost per meter will average somewhere about 88 cts., which is an exceedingly different matter from $3.24 per meter. The cost of repairs and maintenance per meter, in the same way, although perhaps not to the same extent, is materially reduced with the greater number of meters in operation. As to the author's remark that the economic limit of metering is about reached in Rochester, it is hardly necessary for me to say that the

present administration and management of our Water Works disagrees most emphatically with this conclusion. Let us take even his conservative figures in which he states that with the metering of 100% of our services, we would not reduce the consumption by more than 20 gallons per capita per day. In a city of 200,000 inhabitants, to which Rochester very closely approximates, this means a saving of 4,000,000 gallons of water per day. At the figures he gives of the cost of providing a million gallons of water, these 4,000,000 gallons would mean a saving of $271.00 a day or nearly $99,000.00 a year. Is not this enough of an argument for the complete metering of the city?

In concluding this discussion, I would like to call your attention to the last two points in the Author's summary. He mentions the inequality and injustice between the flat rates and the metered rates at which our water is sold. I will merely say that if this inequality exists it is to be eliminated in the near future for we will have no flat rates, as all of our services are to be metered. We are now setting about 20 new meters every working day with our own force and at a cost, as stated before, of between 80 and 90c. a meter. The consumption of water is being reduced per capita per day as is shown by the amount of water delivered each day to the city from our distributing reservoir. This delivery can be figured almost exactly, as all the water coming to the city passes over a weir which has been very carefully constructed and checked.

There is very little complaint from the people who have been put upon the meter basis and we find every day, arguments for the extension and completion of our Meter System. There are at present, (June 15, 1907) in Rochester over 22,000 meters in use which is something over 60% of the entire number of services, and this percentage is increasing every day.

MR. E. A. FISHER: The author is deserving of much credit for the large amount of careful work which he has put upon this paper, and especially for calling attention to the relation that exists between the number of inhabitants per service to the quantity of water used per capita.

As he well says, this condition has been mostly overlooked, and in consequence many statictics as to the relation of meters to per capita consumption are not of as much value as they otherwise would be.

I would agree, for the most part, with the conclusions arrived at by the author so far as they relate to general conditions. There are, however, some conclusions applied specifically to the city of Rochester that do not seem to me to be warranted. I refer at present only to the last four.

The author states that the cost of supplying water in Rochester, including the total maintenance account, is $67.75 per million gallons, while the meter rate for selling water is $140 per million gallons. This statement is based upon the total maintenance account divided by the total quantity of water delivered to the city. No account is taken of the waste, or of water used for general public purposes. Making an allowance of 33 1/3 per cent for water unaccounted for, and assuming that the water used for public purposes is paid for from the general fund at the same rate as are all the private consumers, we find that the actual cost is over $100.00 per million gallons, instead of $67.75.

In conclusion No. 18, the author says that the fixture rates in 1904 paid $147,957.47, while the meter rates, or 37% of the total, paid $277, 137.21. He says this shows an inequality and injustice between the fixture rates and the metered rates which should be corrected. Had the fixture rates yielded at the same rates as the meters they would have produced $471,882.28, and the total income of the Water Works, instead of being $425,094.68 would have been $749,019.49. This conclusion is evidently founded on the assumption that all of the water, except that passing through meters, is used through fixtures. A large portion of the remaining unmetered fixtures are in dwellings that pay from $8.00 to $12.00 per year. If the fixture rates were raised, as recommended by the author, these dwellings would pay more than three times what they do now, or from $24.00 to $40.00 per year. The owners of such premises could afford to put in two meters every year, rather

than pay such rates. There certainly would not be any fixture rates of this character left after the first year.

The last conclusion, that those water takers that pay meter rates pay 100% profit while those that take water at flat rates receive it at far less than cost, is not borne out by the facts. It has already been stated that the actual cost of the water used is at least 50% more than was stated in conclusion 16.

The following statistics relating to the actual consumption of water in a number of dwellings may be of interest in this connection. During the year 1903 the Mayor, in his Annual Report, had a very voluminous discussion of matters relating to the water supply of the city of Rochester, and among other details the report contains a table of the amount of water consumed by 15 recently metered services for 30 days in 1903, compared with the same services under flat rates with the corresponding period of the year before. The total amount of water used through the 15 services in the period in question during the year 1903 was 83,404 gallons. The total amount of water allowed, according to the flat rate in force before the meters were put on, was 89,826 gallons. It is therefore seen that if the 15 dwellings referred to had paid a flat rate, instead of a meter rate, they would have paid more for water than the 14 cents per thousand gallons that was actually paid under the meter rate. These 15 dwellings had 66 occupants. The average use per capita per day was 42 gallons. Only four out of the 15 used more water than they would have been entitled to under the flat rate. One of them used a little more than three times as much as it would have been entitled to under the flat rate.

The report also contains another table of water allowance on 13 flat rate services for 30 days in the months of August and September, 1903, with the amount registered by meters set thereon experimentally, for that period. As one of these services was a livery stable I have omitted it from the summary, and as another of the services had a bad leak I have considered this account separately. This leaves 11 accounts to be considered.

The total water used in the 11 dwellings was 61,368 gallons. The total amount that the 11 dwellings would have been entitled to, under the flat rate, is 61,473 gallons. It is therefore seen that the flat rate paid by the 11 dwellings is almost exactly what they would have paid at a meter rate. The one dwelling referred to showed a use and a waste of 62,992 gallons, or more than the total of the other 11 dwellings, proving conclusively that there was a considerable leak in this service, to which the meter called attention, and the leak was repaired. The total number of occupants of the 11 dwellings was 70, and the average use 29 gallons per capita per day.

The use per capita per day in the one case referred to was 209.9 gallons; the average of the 12 dwellings, which includes the leaky service, was 58 gallons. The result shows that the actual use of water through the ordinary dwelling house service in this case corresponds very nearly to what the dwelling is entitled to use under a 14 cent rate.

The following additional facts relative to the relation between cost of water by meter and that according to flat rates, is also of interest. In 1902 the speaker had prepared by the Accounting Department of the Water Bureau a table showing the income from 234 metered accounts, and also what these accounts would have paid at the prevailing flat rates. They are divided into three classes.

1st. Consumers that paid by meter ..... $5.00 per year.
2nd. Those that paid ..... $10.00 per year.
3rd. Those that paid .....$25.00 per year.

Eighty accounts of the first class, or those paying $5.00 per year, were taken. The actual amount paid by these 80 was $402.34 or an average of $5.03 each. These 80 services would have paid $905.00 under flat rates for the fixtures then in use, or an average of $6.28 per year more than they did pay under the meter rate. This is more than double what they actually paid. These consumers, therefore, could afford to pay for a meter every two years, rather than pay the flat rate.

Seventy-nine accounts were considered of the second class that paid $10.00 per year. The actual amount paid

by these 79 accounts was $788.68, or an average of $9.98 each. The amount that these 79 consumers would have paid under the prevailing flat rate for the fixtures then and now in use was $1,206, or an average of $5.28 each more than they actually paid. In the third class, paying $25.00 75 accounts were considered paying $1,841.26. These 75 accounts would actually have paid $1,730.50. They actually did pay $1.48 more under the meter rate than they would have paid under the flat rate. It should be considered, however, that these 75 consumers were permitted to sprinkle, by using a meter, and under the flat rate were not allowed to sprinkle, thus offsetting more than the difference of $1.48.

This table, made up with care—the accounts taken at random from total number of accounts—shows that the average dwelling having the usual number of faucets, one bath and one closet can, by a reasonable use of water, at the 14 cent rate, secure their water supply at a much less outlay than through the present flat rates. The conclusion, therefore, is that the present flat rates for dwellings are not too low, but that they actually are for the domestic users of water higher than the 14 cent meter rate.

All large users of water are already metered. Those remaining are generally dwellings the water for which is classified under the head of *Domestic* use. From the statistics already given it is evident that the ordinary Domestic consumer can afford to pay for a meter on his service in order to obtain the present 14-cent meter rate. This inducement to put on meters was held out to the property owners, and the tests already referred to, as well as others which might be mentioned, show the correctness of this conclusion.

MR. FRENCH: One detail of this subject has not been touched upon, or at least I have not noticed that it has,—I refer to the care a meter should receive.

We do not have to make any very diligent inquiry to learn that meters are frequently purchased and put into service and allowed to remain until they quit business or break down. If we buy a new pumping engine, new boilers, or any other additional plant equipment, it receives

careful and uniform attention on the part of somebody, but in the case of a water meter, the yearly cost of which is heavy, particularly so if the system is a universal meter system, the machine is frequently set in an inaccessible out of sight and out of the way place, and yet we expect the machine to go along about its business and furnish us with accurate results. There is no doubt but that there are meters in operation today that have been running for 20, to perhaps 25 years, but personally I have no sympathy with this practice, and if a man has much interest in accounting for the highest percentage possible of his total pumping, he cannot afford to let his meters run 20 years, or more, without giving them attention.

Some years ago the Hackensack Water Company instituted the practice of looking after its meters in some systematic way, and which has proven to be very satisfactory.

We have thirty odd thousand meters working, and when the quarterly readings of these meters are taken, every ½" meter that has passed 100,000 cubic feet, every ¾" that has passed 500,000 cubic feet, and every 1" that has passed 1,000,000 cubic feet is taken out and put through the meter repair shop. A ½" meter to have passed 100,000 cubic feet has been in service from 8 to 12 years.

We are particular to follow up closely all meter tests and especial emphasis is placed upon the fact that every meter brought in that will run, must be tested, and our tests show that meters that have passed the quantities mentioned generally register from 4% to 6% against the Water Company, and inasmuch as the expense of restoration is small, it is not only good financial business, but at fairly regular intervals the practice brings one into touch with all of the meters set on the system, and gives one the satisfaction of feeling that he has the meter question well in hand, and the certainty of knowing that the meters are not running 10% to 30% wild, not mentioning the loss in revenue.

I have found the cost of repairing 100-½", 100-¾", and 100-1" meters, after passing the quantities referred to, including cost of making the changes, also all labor and material entering into the repairs, to be as follows:

½"—0.57 of 1% of cost of $12.00=0.052 c each per an.
¾"—0.376 of 1% of cost of 21.00=0.0564c each per an.
1 "—0.497 of 1% of cost of 30.00=0.0541c each per an.

The average inaccuracy of these meters on test was as follows:

½"—0.043 %
¾"—0.0476% } against the Water Company.
1 "—0.0497%

MR. VOLKHARDT: I would like to ask Mr. Rafter if we are to understand from his paper that his contention is that it does not pay to meter more than 50 per cent of the taps on any system? Do we understand that to be one of your claims?

MR. RAFTER: Yes, I think so.

MR. VOLKHARDT: I think I shall have to differ with Mr. Rafter on that. In my study of the meter question I have tried to keep pretty close to it, and I think you will find that the saving of waste will be among your domestic consumers, and if you only meter 50 per cent. of your plant, the other 50 per cent. which you do not meter, will be your domestic consumers, and you will not get the same results you would if you were to meter your entire system. Furthermore, a system with 50 per cent. metered would naturally take in the large consumers first, such as manufacturers, commercial users and some domestic; it appears to me, and I find others take the same view, that that is very largely a matter of discrimination. The large consumer often takes the stand that you have placed a meter upon his industry, and are making him pay for every gallon of water. He knows that he is not getting all that he is paying for at his residence, he makes a demand for a meter there, and it is a pretty hard thing to refuse him. A plant being only half metered, or partially metered, certainly would not produce the net results or increase of revenue that a universally metered plant will show. At least such was the case with every plant that I have had the pleasure of investigating and rearranging. I have heard the same fact cited right here on the floor.

I would say to Mr. French that I do not know whether the information that he has just given has been cited on the floor before or not, but I can say from my own experience, that there are many plants following a similar practice and overhauling their meters after they have passed the quantities of water such as he mentioned.

In reply to Mr. Tighe and that part of his paper wherein he thinks it would be difficult to arrange a meter rate on a new plant, I have found by experience that it is much easier to arrive at a proper rate with plants that have already been established, and that are earning a certain amount of revenue, than is the case with a new plant. With the latter, it is difficult to estimate at first just how much your prospective users will probably consume. In the case of an old plant, you are already earning a certain amount of revenue, and it is simply a mathematical problem to find the proper rate. I have also known of places that have tried to get along on a flat meter rate. I do not know of any universally metered plants that have a flat meter rate, and I do not really believe that any such plant can live with but one flat rate. Take for instance, the rate that Mr. Tighe mentions. I believe it would play havoc with his revenues if he were to extend that to the domestic supply; on the other hand, if he were to select a rate that would fit the domestic consumer, his large consumers, would complain. I would like very much to hear something along this line, with reference to universally metered plants having flat meter rates, and what results have been obtained.

MR. CHESTER: I think the result of flat meter rates put into universal use would simply eliminate the large consumers, such as railroads, large manufacturers and others that could better afford to pump their own supplies, therefore, it would not be practicable. As to the matter of rates, I believe there is too universal a tendency in getting up a schedule of rates to get hold of other people's schedules and sort of strike an average. Very frequently after a schedule is put into use, it is found to be impracticable and changes have to be made. Just now, around Pittsburg, in the suburban water works under private ownership, there have been

many suits brought into the courts. I have in mind one that will be tried next week touching the rates charged. In one case the patrons of the privately-owned plant are being charged at a 40 cent rate, while another plant nearby is selling water at a 20 cent rate. One of these localities is a small borough which was built or laid out by a manufacturing company, and all of the houses were built for their employees, by whom they were occupied. The tenants of these houses were furnished water by the manufacturing company and charged a flat rate for it, which in my opinion, was really less than the cost of pumpage. On the other hand, the other borough is a residence suburb which was laid out not for factory people but for people with incomes ranging at not less than $5,000 to $10,000 per year, and in the first case for every 50 feet there were probably two consumers, in the second case, there was not more than one consumer to every 300 feet, or 400 feet of main, still the people in the residence suburb do not understand why they cannot have water for 20 cents per 1,000 gallons. In reality, if they were charged 30 cents per 1,000 gallons sufficient income would not be derived to pay the interest upon the actual investment and meet the operating expense of the plant. While in the other case, the operating company are declaring good dividends. The matter of what any water works management can charge is as held in the President's Paper this morning, largely a local matter. As stated in another paper, the making of rates is an important item and calls generally for the experience and the knowledge of an expert. In regard to metering, I must agree with Mr. Rafter in one way. The metering of more than 50 per cent. of the consumers has often in my experience resulted in cutting down the revenue; that is, the revenue was generally increased by the metering of 50 per cent. of the consumption, and after that it would begin to decrease, not from the original amount or the flat rate amount,but an increase cannot generally be secured beyond metering of from 40 to 50 percent of the consumers. Therefore, looking at it from the standpoint of revenue, in which we are all interested, no matter whether the plant is municipally or privately owned, I would not advocate meter-

ing beyond that percentage. On the other hand, there are many times when we have to look beyond that in the case of our water supply and consider our reservoir capacity, impounding capacity, and the means of bringing the water into the city, the pumping capacity, and a great many other things, and we will then find that unless we continue to meter beyond 50 per cent. we will have to increase our investment along other lines Metering beyond 50 per cent. will generally cut down the consumption, but this again is largely a matter of locality and surroundings. The southern plants I believe will all testify that the negro or colored citizen is not personally a great water user, but he is an extravagant waster—prone to let the water run all the time in summer as well as winter, he has not the excuse in the South that we have in the North, where we let the water run to keep cool in the summer and to keep it from freezing in the winter. He lets it run for some reason or other —perhaps because he likes to hear it? Consequently in the Southern cities we make a greater saving of the water supply by metering beyond 50 percent than we can in the Northern cities. In cases where you have an Italian population, such as Italian boarding-houses and such things as that, you will be surprised at the saving you can make by metering, for when the Italian finds that it touches his pocket book every time the meter ticks he will be more economical in his use of the water, but if he has been paying a flat rate of $7.00 or $8.00 then that Italian or that negro is not put on a minimum, he knows that he will only have to pay that much at the end of the year and he will consequently waste water. In a borough near Pittsburg, the inhabitants of which are largely railroad employees, about 90 per cent. of them use less than the minimum, and they never over-run it. As I said before, metering beyond a certain percent is a matter of conserving your water supply, as well as saving the wear and tear of your pumping machinery. When called upon to give advice as to the using of meters, and what percentage to meter, I consider all of these things, and if I am asked where to begin metering I would certainly say, first the factories, and after that the commercial interests. I believe that factories are large

wasters, especially where there are open ends to be used by the employes at the factory, such as hose for washing, especially at railroad shops, and foundries or anything of that kind where there is a necessity for a large opening. They will use the hose for a while, and then when they should shut it off they neglect to do so, but let it run if there is nothing to prompt them to shut it off, no inspector or orders on the part of the employer. A large saving is always effected by the metering of such consumers. You will find equal waste in the case of a saloon where they use water for washing glasses, and so forth. The bartender will allow the washing apparatus to constantly run. The metering of the saloons in one part of Pittsburg shows a decrease in consumption of 10 per cent., there was a large number of saloons there. I firmly believe that there is need for such an expert as referred to. There is need for a full consideration of all the surroundings, and all the matters entering into the question of revenue, whether it is the question of water supply, or mains, pumping machinery, or whatever it is. It is impossible to lay down a hard and fast rule. If you could there would be no use for an expert, and there would be no living for the engineers in this country, if you could figure a rule out to apply in all cases as a mathematical proposition.

MR. VOLKHARDT: Mr. President, I am ready to admit that some cities, partially metered, would make a better showing, if metered up to 50 per cent. using their present rates, but it is quite different in the case of a new plant that has no meters at all, at that time you have the opportunity to consider all local conditions present, and to anticipate future uses all of which can be done without injury to the welfare of the plant or any of its large consumers. At the time of making the rate on the existing partially metered plants local conditions may not have been considered, as the custom has been to strike an average on what some neighboring plants charge. I have studied several schedules of partially metered plants and I am satisfied that in each of those cases if the entire plant had been metered at the same rate, they would not be successful.

In establishing a meter rate, whether you intend to start with a small number or have in mind a universal system at some future time, one should at least provide for ten succeeding years, you must anticipate the future or you are at a standstill in later years. Heretofore, we have not had as much knowledge on this subject as we have to-day, we are progressing, and it is within the bounds of possibility that some of those partially metered plants with apparent slight changes could be changed and become successful.

I do not think there are two cities in the country to which the same meter rate can be applied all the way through. Referring to the instance cited by the previous speaker of the two boroughs where the 20 cent rate and the 40 cent rate were in operation, calls to my mind a case somewhat similar. It is a private company selling water to a purely residential section and charging only 10 cents per thousand gallons. I was curious to know how they could afford to sell at that rate. I was informed that the water plant, land and buildings belonged to one concern and the low water rate was adopted as an additional inducement to locate there. As I stated in my paper, local conditions must be considered to be successful and produce results with a meter system.

Mr. Thomas: I understand that the Legislature of Massachusetts very recently passed a law compelling cities and towns in the Metropolitan District supplied by the Metropolitan Water Commission, i. e., cities and towns within ten miles of Boston, to meter five per cent of their unmetered services every year till all are metered, also that all new services must have meters placed upon them. The bill at first met with a great deal of opposition, and the argument that was used in its favor, and which finally prevailed and convinced the members of the Legislature that the measure was a just one, was the fact that the water wasted in the Metropolitan District was needed and of great value to the country several miles from Boston, from which the

supply was drawn, and that in the interior part of the State a number of industries using the natural flow of the streams for power; etc. would be deprived of such use, which in connection with the generation of electricity from which they could develop considerable power, would be of great profit and benefit to the people of the towns if the waste was prevented and the Metropolitan District which was using such an excessive amount of water, was compelled to use meters, instead of taking up and absorbing the water resources of the State, without a thought for the rights and needs of others. Consequently the Legislature was prevailed upon to pass the Act in the interests of the prevention of waste . It seems to me that this is the great consideration which should not be lost sight of in connection with this meter question, and that it is of equal importance with the other consideration, of securing equitable treatment as between consumers so that each individual shall pay his proportionate assessment toward the revenues of the plant. The idea that the prevention of waste should be ignored because it is going to reduce the revenues of the department seems to me is taking a too narrow view. If, by the prevention of waste, thereby preventing the loss of a valuable commodity, the revenues of a department prove insufficient, then there should be a proportionate increase in the rate charged to water consumers. Do not permit the waste of this valuable commodity through fear that the revenues of the department will not be sufficient. It has always struck me that there would be as much justice in allowing the citizens of a municipality to go up to the coal bin of a water works pumping station and help themselves to the coal as to permit them to waste water, that coal must be consumed to pump the water. While the taking of the coal direct strikes us more forcibly, yet it is no less justifiable than allowing the water to run to waste in the sewers. Where is there a city or town, not certainly in the east, where the waste of water is justifiable, even though it may keep our revenues up? I think that one of the first things we ought to aim at, is to conserve our water supply and utilize it for every purpose that can be of public benefit, instead of allowing it to run to waste.

MR. SAUNDERS: In reference to the meter question, as one of the representatives of the city of London, (Ont.), we were considerably interested, and there is one phase that appeals to us there that has not been touched upon at this meeting, and that is this: The speakers all argued that it was a good thing to save water. The attitude that we take in London on that matter is this, that it is a good thing to save water if we can do so at a reasonable expense, but if it costs us $150,000 to save $100,000 worth of water, we do not think it is economical. If some of the gentlemen from New York would treat on that matter or if the President would rule that it might be considered, it would at least to us London people be very interesting.

MR. VOLKHARDT: I might be able to give you a little pointer on that. When I was connected with a certain water plant I had two stations pumping 24 hours, and after we had 1000 meters on we were able to dispense with one of those pumping stations. The two stations were burning 2000 tons of coal while they were both going. But when one was shut down the remaining one only burned 900 tons. The coal cost $4.00 a ton, thus effecting a saving of $4,400 on the one item of coal. We paid the engineers $3.00 a day and the firemen $1.75. We saved another $4,000 there. Our revenue increased something like $3,700. In other words, in fourteen months I got back all that my meter system cost me, and after that, as the saying is in America, everything was "velvet." With a properly designed plant I am satisfied you can increase your revenue by metering. It has always worked out that way so far as I am able to learn.

MR. RAFTER: The paper on The Cost of Meters at Rochester was written primarily to illustrate the relation between the number of services and the number of inhabitants per service. The city of Rochester was taken as an illustration (1), because the writer is familiar with metering in that city; and (2), because it affords a good illustration on the point to be illustrated.

In view of the showing made by the writer it will be a matter of surprise to learn from Mr. Little that the cost of meters at Rochester is a question which is of especial im-

portance only to the taxpayers of that city. On the contrary, the whole meter business is a series of discussions of special conditions in particular cities applied to the general problem. It may, however, be more a matter of surprise to learn that the statistics cited in the paper are all in the Annual Reports of the Department of Public Works of Rochester and have been compiled by Messrs Fisher and Little. If my statistics are wrong, therefore, we shall have to charge it up to errors in the statistics of the Rochester Water Works.

Mr. Little refers to some statements made by Mr. Emil Kuichling, former chief engineer of the Water Works. These statements are not in the report quoted by me, but in the 16th Annual Report, at page 47. The statements referred to are as follows:

> Although it is at present impracticable to make an exact enumeration of the consumers represented by the 798 domestic metered accounts, yet as a majority of these accounts are for apartment and boarding houses, it is fair to assume that at least *ten* people are represented by each account, whence it follows that the consumption becomes about 45 gallons per head per day. Further investigation may show that there are more than *ten* inhabitants represented by each account, in which event the amount per capita would be somewhat less.

The foregoing statement of Mr. Kuichling is made in regard to 798 domestic meters and was a mere guess, while the statement made by me is in regard to 2733 domestic meters. Does Mr. Little mean to claim that there are 2733 hotels and boarding houses in Rochester? The Rochester City Directory for 1907 gives the number of hotels in the city at 43 and the number of boarding and lodging houses at 60. In 1892, the same authority gives 35 hotels and 103 boarding houses. If we allow an average of thirty persons to each of the 138 hotels and boarding houses in Rochester in 1892 and 5.3 persons to each of the other 2595 domestic accounts, we find that the ratio for the entire number of 2733 domestic accounts is, on this basis, 6.5 persons per service, which is certainly ample.

Mr. Little states that the metering in Rochester in a careful and systematic way only began in 1905. He says that before that time a comparatively small percentage of the services were metered and each year saw only a small num-

ber of meters added compared to the number that are now being annually installed. The meter department of Rochester was in reality started by J. Nelson Tubbs, M. Am. W. W. Assn., as far back as 1878. The intention was to meter large consumers from year to year gradually increasing until about one-half of the total number of services were metered and then discontinue. Experience in Rochester and elsewhere has demonstrated such a policy to be the best, both from the point of view of the taxpayer and the water works manager.

In regard to the reduction in the use of water and the value of the same, thereby effecting a saving of nearly $99,000 a year, the remarks of Mr. Little are singularly appropriate—that if it costs more to save water by metering than the value of the water saved, the metering is not very economical. This is precisely the case at Rochester and in very many other cities in this country where universal metering has been gone into. The saving thereby accomplished is more than counterbalanced by the increased cost of running the meter department.

We may conclude this discussion with the following quotation from a paper entitled Some New Facts Relating to the Effect of Meters on the Consumption of Water by William S. Johnson, Assistant Engineer Massachusetts State Board of Health, in the Journal of the New England Water Works Association for June, 1907:

> During the past ten to twenty years great numbers of meters have been introduced and now in many places the percentage of metered services is as great as in the cities which have so long served as examples—but the predicted saving in water has not been accomplished. On the contrary, an examination of the figures of consumption shows that the rate of increase in the use of water in Brockton, Fall River, and Providence is greater than the rate of decrease in many of the places where meters have recently been introduced, indicating that if the consumption in these other cities ever becomes the same as that of Brockton, Fall River, and Providence, the latter places are likely to meet the others halfway.

* * * * * * * * *

From a consideration of the foregoing facts it is evident that disappointment is inevitable in the case of many cities and towns where meters are being introduced.

SOME NOTES ON RULES, ORDINANCES AND COURT RULINGS GOVERNING THE OPERATION OF WATER PLANTS.

By S. J. Rosamond

The first important question between the prospective consumer and a water department is the introduction of a service into his premises and is usually covered by a rule reading as follows:—

1.—Water shall not be introduced into any premises without application having been first made at the Water Works office and granted officially.

2.—Every application must be made by the owner of the property to be benefitted, or his or her authorized agent, according to the form prescribed by the Board of Water Commissioners, or the Water Company.

Another form and perhaps a better one is as follows:—

All applications for service attachments to the distributing pipes, for the purpose of introducing the water into any premises, as well as all applications for the use of water, must be made by the party desiring such attachment or use of water, and always with the consent of the owner of the premises into which the water is proposed to be introduced. The applicant must state fully and truly all purposes for which water is required, and frankly, without concealment, answer all questions asked by the Water Company's authorized agents relative to the consumption, sign on the Water Company's books an application setting forth the purposes for which the water is desired, and agreeing to abide by the rules and regulations of the Water Company relating thereto. Upon complying with these conditions the Superintendent of the Water Company will issue a written permit granting the applicant the privilege of a service attachment and the use of water in the manner and for the consideration as hereinafter stipulated.

This brings to the notice of the prospective consumer the rules and regulations under which he or she are to be supplied with water and makes it the duty of the consumer to inform himself as to the restriction placed upon the service.

A good form of contract or consumers' permit is as follows:—

CONTRACT FOR WATER SUPPLY.

All bills, except for meters and elevators are payable quarterly in advance. Due the first of January, April, July and October. Meters and elevator bills are payable the first of each month for the preceding month.

TO THE MUNICIPAL WATER WORKS COMPANY,

M..... is authorized to have service pipes connected with the mains, to supply premises situated on ..... street, between ..... and..... streets, said M..... as applicant, hereby agreeing to at all times abide by the rules of the Municipal Water Works Company, and hereby acknowledge the penalties following a violation of the rules. The water to be used for the following purposes to wit:—

.....

.....Applicant. Municipal Water Works Co.
By.....Supt.

The rules of an incorporated Water Company require all applications for the introduction of water into any premises to be made in the handwriting of the applicant, and to be made with the written consent of the owner or agent, when the application was made by a tenant, and provided that, when water rent was past due, the Company might shut it off.

S., under the rules, ordered and received water for his premises, but during its reception, conveyed the property to his wife, who continued to receive water under said order,

S., acting as his wife's agent for the property while she so received water. The Company having no knowledge of the conveyance, made no demands upon the wife for water rent, but made several such demands on S., who failed to pay. The Company started to shut off the water, when the wife brought injunction. Held, that it would not lie.—Smith V. Scranton Gas & Water Co.—5 Lack Leg. N 235.

3.—All work done in connection with the service pipes, fixtures, etc., shall be done by a competent plumber, holding a license from the water department, and who has filed with the water department, a good bond, in the sum of not less than Two Thousand ($2,000.00) Dollars.

Plumbers should be required to take out a written permit for each job before doing any work on the service pipes, fixtures, etc., and a record of each permit should be kept in the office of the water company, of each permit taken out. A good form for this permit is here inserted.

4.—Every plumber, within twenty-four hours after having set up any pipes, water-cocks, or other fixtures, or having made any alteration or addition to any pipes, cocks or other fixtures, already set up, shall make a correct return to the Superintendent in writing, with a diagram descriptive of the work done, stating the ordinary as well as the special uses to which the water is to be applied, in order that the proper knowledge of the amount of water used upon the premises may be obtained therefrom. A failure to comply with the above will make a forfeiture of his license at once. Water will not be turned on at any premises until complete returns shall have been made in writing by a licensed plumber, permission first having been obtained in writing from the Superintendent.

5.—There will be no concealment of the rent, purposes and extent for which the water is to be used. When such concealment is ascertained, the water will be turned off until the application is renewed and made satisfactory to the Company. And here the question

SERVICE PERMIT

Fort Smith, Ark., .190.

M.

is authorized to have service pipes connected with the mains, to supply premises

Street

No.

Rooms			
Bibb			
Wash Basin			
Bath			
Sink			
Water Closet			
Urinal			
Cow — Horse			
Street Wash			
Yard Hyd			
Store			
Boiler			

Face p. 40

Unless the Plumbing is done in Strict Accordance with the Rules of the Company the Water will not be Turned on

SERVICE PERMIT

OFFICE OF MUNICIPAL WATER WORKS COMPANY

FORT SMITH, ARK., .190...

M..... ...is authorized to have service pipes connected with the mains, to supply premises situated on.

Street, between.. and.....Streets, with water

MUNICIPAL WATER WORKS CO.

Per.....

PLUMBER'S REPORT

FORT SMITH, ARK.,... 190

The following fixtures have been attached as authorized in the above permit:

.in Corporation Cock in Main Pipe..

..ft. of.....in.....Pipe to Stop Box

One Stop Box and Cock at Curb Line.....

ft. of.....in.....Pipe from Curb Stop to

Stop and Waste Cock at.....

Rooms			
Bibb			
Wash Basin			
Bath			
Sink			
Water Closet			
Urinal			
Cow — Horse			
Street Wash			
Yard Hyd			
Store			
Boiler			

and the water left **OFF**; all work done as required by the rules of the Company, reference being made to the accompanying diagram.

....., Plumber

Feet Front	Remarks

Plumbers will make diagram here, showing location of the Tap, Stop Box, Pipe Line, at least three streets and adjoining premises each side.

Diagram must be made specific and so completely accurate that the Stop Box can be found easily. Plumbers to give street number, to state whether bibbs or hydrants are "plain" or with "hose connections," and always take out a permit for each Stop Box where more than one street number is supplied.

arises as to the right of a water company to make and enforce rules governing the supplying of water. This question has been passed on by the Courts in most of the States, some of which are as follows:—

(Tenn. Ch, App. 1899).—While a public water company is a quasi-public corporation, and bound to supply water to all persons, without discrimination, and such companies may nevertheless adopt reasonable rules for the furtherance of their business, which may be enforced, even to the extent of denying water to those who refuse to comply with them—Harbison v. Knoxville Water Company, 58 S. W. 993.

(Tenn. Ch. App. 1899).—One furnished with water by a City water company, having supplied an appliance to his hydrant, so it could be used for both domestic and sprinkling purposes, cannot afterwards compel the Company, in violation of its rules, to supply him with water for domestic purposes only, without changing such appliance that the hydrant could not be used for sprinkling purposes.—Harbison v. Knoxville Water Co. 53 S. W. 993.

6.—No person or family supplied with water by the Water Company will be permitted to use water for any other purpose than that stated in the application or agreement, or that estimated for fixing the rates, nor supply water in any way to other persons without a written permit from the office of the Water Company, nor permit others to use their hose or attachments, or leave them exposed to use by others.

7.—License for water for building purposes will be issued only on certificate of the architect or builder of the work to be done, specifying the number of brick, perches of stone, square yards of plastering, and other uses for which water is wanted, and in all cases payment must be made in advance. Applicants shall notify the Company when such work is completed so that the water may be shut off.

The writer has been unable to find where this rule has ever been in controversy and therefore is unable to find decisions bearing on this, except the one herein

contained giving water companies the right to collect water rents in advance. (See Tenn. Ch. App. 1899 under rule No. 27).

8.—No alterations or extensions of any water pipes or fixtures shall be made without first giving notice of such proposed alterations, or extensions, and securing a permit from the water company authorizing the same, and the work must be done by a competent licensed plumber.

9.—All connections with the mains shall be made by the Superintendent or his representative (and no person but the superintendent, or his representative, shall turn on water to any premises. Each service must be provided with a stop cock, protected by an iron box, cover on which is marked "WATER," and said box shall be kept on grade with the sidewalk, just inside the curb line, and accessible to the Water Company's inspectors at all times. A stop-and-waste cock shall be placed on each service pipe where it first enters the building, and each service shall be so constructed that the water can be drained out of the pipes by said stop-and-waste cock to prevent pipes from freezing, or for other purposes. All services must be capable of withstanding a pressure of 300 pounds per square inch.

(Idaho, 1900).—When a Water Company undertakes the performance of a public duty, it devotes its property used for that purpose to a public use, and may make such reasonable regulations for the conduct of such business as may be necessary; and a rule reserving the right to the Company to make all taps on its mains and pipes is a reasonable one.—Pocatello Water Company v. Standley 61, P 518.

10.—Consumers shall prevent any unnecessary waste of water, and be required to keep their sprinkling hydrants, faucets, valves, hose and all apparatus, including stop boxes, in good condition, and at their own expense, and all water ways closed when not in use. Water will not be turned on leaky or defective fixtures, and will invariably be withdrawn when so found.

11.—A service pipe or tap intended to supply more

than one dwelling or premises, must be provided with a separate stopcock, and box placed on the curb line of each premises or dwelling, and in case where more than one premises or dwelling is supplied from the same service pipe, and a separate box and stopcock has not been provided for each premises or dwelling, then the Water Company will only contract with one of the parties so supplied, and in case any of the parties so supplied, violates the rules of the Water Company, then the whole supply will be shut off until the matter is adjusted to the satisfaction of the Water Company.

12.—No plumber or consumer shall turn water on to any premises, whether old or new supply, except for the plumber to test the work, but the plumber on completion of the work, shall leave the water OFF and return his permit to the Water Works office, then the Water Company will have the work inspected, and turn the water on, provided the work is acceptable and all dues paid.

13.—The season for sprinkling lawns, gardens, etc., is from April 1st to October 31, and no license will be issued for a less time. Any fixture provided with hose attachments shall be charged sprinkling rates in addition to other uses available. (See Tenn. Ch. App. 1899).

(Pa. Com. Pl. 1900).—A city will not be enjoined from turning off a water supply on a consumer who disputes the amount of a city's bill for water rent, since the consumer can pay under protest and recover by suit at law.—Penn. Iron Co. v. City of Lancaster. 17.—Lanc. Law. Rev. No. 161.

(Pa. Com. Pl. 1900).—The fact that the shutting off by the City of plaintiff's water supply for non-payment of water rent would also shut off from a city fire plug, and deprive plaintiff to that extent of fire protection, is not a valid reason for enjoining the City from so shutting off the water.

A like case was taken into the Courts by a consumer at Little Rock, Arkansas, in 1902 and was decided as follows:—One Baker, brought suit to enjoin the Home Water Company from shutting off his water, the Com-

pany having threatened to do so on account of Baker not having paid for the sprinkling service. Baker had paid his domestic rate, but had refused to pay his sprinkling rate for the same year, and the Water Company threatened to shut off his water. Baker sought to enjoin the Company and the defence of the Water Company was as follows:—That Baker was bound to pay for water for sprinkling purposes so long as his fixture was attached to the service pipes; that the rate fixed by ordinance for sprinkling was a rate for the entire year, and was based on the consumption of water during the entire year, which was well known to exist only during a period of six months, or a sprinkling season from April 1st to October 1st, that all water rates are based on the volume of water consumed, and it would be a fraud upon the Company to permit the consumer to pay for water during the sprinkling season monthly at one-twelfth of the annual rate, and to cease the payments when the sprinkling season ended, that the effect of such an interpretation of the ordinance would be to cut the water rate to $5.00 per year instead of $10.00 per year. The terms of the ordinance in that respect reads as follows:—

"The Home Water Company is hereby authorized to charge all private consumers the following prices per annum, as water rates, to wit:—

Street or yard sprinklers, $10.00 per year each up to fifty feet front, and ten cents for each additional foot—Side of lots charged at the same rates. No hose will be allowed for sprinkling unless other rates are paid on the premises.

The rates above specified shall be and continue a maximum rate and shall be paid monthly in advance, and said Company is hereby ordered to charge such persons and consumers as may desire to elect to pay for water privileges by the gallon, maximum rates as follows:—"

The Court dismissed the bill of Baker and dissolved the temporary injunction on the grounds that he was liable for water rent for sprinkling purposes so long

as his fixture was attached to his service pipes, and in so doing the Court held:—

1st.—That it was the duty of the consumer, if he desired to cease the water for sprinkling, to remove the sprinkling fixture at his own cost. The Court further held in that connection that it was the duty of the consumer to provide their own fixtures and to keep them in good repair, and to provide and keep such fixtures as would prevent waste of water, and if they permitted a waste of water that the Company would have the right to turn it off, and the Court would protect the Company in the exercise of its right.

2.—That under the ordinance all water rates were payable monthly in advance, and the Company could not enforce payments for more than one month at a time, and that the sprinkling rates did not differ from the other rates, and was divisible into twelve parts, the consumer being entitled to begin and cease the use of sprinkling at any time he desired, provided he paid for the same monthly in advance, and if he desired to use it for only two months during the sprinkling season he might do so, and only pay for each month one-twelfth of the annual charge, and when he ceased the use of water, would not be required to make any further payments on account of sprinkling.

14.—Sprinkling must be done with hand hose, and any revolving sprinkler, fountain jets, or device for holding or converting the hose into a fountain or jet will not be allowed unless special permit is issued therefor at fountain rates. No lawn sprinkler shall be allowed on sidewalk of residence property. Lawn sprinkling is limited to three hours per day during the sprinkling season, and no sprinkling shall be done at any other hours than between 5:30 A. M. and 8 A. M. or 5:30 P. M. and 8 P. M. No sprinkling shall be done during a fire alarm. Street sprinklers or pave washers shall be for washing fronts of buildings, or sprinkling one half the street in front of the property for which it is intended, but shall not be used to muddy the street or sprinkle more than the front of said property.

15.—Applicants for water for motors or elevators must furnish an indicator or meter to correctly measure the quantity of water used, and elevators must be provided with a device satisfactory to the Superintendent to prevent the water ram or hammer in the pipe from the sudden closing of the valve. They must in no case use their elevators or motors during a fire alarm, or until notified by the proper authorities that fire pressure is no longer needed. A failure to comply with this rule will result in forfeiture of their license indefinitely.

16.—The Water Company reserves the right at any and all times to shut off water in their mains for the purpose of making repairs, or extensions, or for other purposes, and all persons having boilers or heaters on their premises not supplied by tanks, but depending on the pressure to keep them supplied, are hereby cautioned against danger of collapse.

17.—Consumers vacating premises must notify the Water Company at their office that the water may be shut off, and they will be held responsible for water rent until such notice is given. But after such notice is given and water is turned off, the consumer shall be entitled to a proportion of the whole amount equal to the unexpired part of the quarter.

18.—All persons desiring to sprinkle streets with a wagon or cart must first obtain a permit from the Water Company for each and every cart and wagon used for the purpose. Water from these carts shall not be used for any other purpose than sprinkling the district as prescribed in their permit. Water used or allowed to be used for any other purpose whatever will result in revoking the permit.

19.—Applicants for water for steam boilers for engines must provide tanks to maintain sufficient water for not less than 24 hours run. The Water Company will not be responsible for any damage occurring on account of a failure to comply with this agreement.

20.—Water fixtures in exposed positions are assessed each and every purpose available, and for each

family and establishment within the same enclosure, or separated only by gateway, door or other means of easy access or communication therewith.

21.—Water will not be supplied to any premises for any special purpose alone where available for other purposes. No hose bibbs will be allowed on inside work.

22.—No rebates from the rates will be allowed for partial use of cisterns, wells etc., nor for not using any fixture. If any fixtures are not wanted have a licensed plumber to disconnect them from the service pipes, when their rates will be stricken off, provided that this does not conflict with other rules and regulations.

This rule was found to be a reasonable one, as will be seen from the case at Knoxville, Tenn., and also the one decided at Little Rock, Arkansas.

23.—Water consumers are not guaranteed a specific quantity of water for any purpose whatever, but simply an ample quantity for the purpose named in the permit. All other uses may be regarded as a direct violation of the agreement between the Company and the consumer, and are subject to such penalties as the Company sees fit to impose, in addition to paying for such unlicensed uses of water.

24.—Any consumer making application for meter to be set in his premises, must pay all cost of setting and keeping said meter in repair, said meter must be perfect and reliable and acceptable to the Water Company. They shall be sent to the Water Company's office at least twenty-four hours before wanted to be set, to be tested by the Superintendent, and must be placed by a licensed plumber.

25.—All meters must be placed in a position readily accessible to the Company's inspectors and secure from freezing. A stopcock must be placed on service pipes not more than one foot from the meter. This in addition to the stop and watercock, which must be on all service pipes at entrance to building. No meter shall be removed from any premises where it has been placed, except on written permission from the Superintendent.

The Water Company reserves the right to set meters where it may deem necessary, however, any meter furnished a consumer by the Company shall not return less than —— per month.

This brings up the question of the right to charge a minimum, and the writer thinks this is pretty well covered by a case that was taken up in Missouri which is as follows:—

(Mo. App. 1898.)—Where a contract for water rates has no charge for meter inspection the Company may fix a reasonable charge for such inspection and also a minimum charge for water used in a quantity less than provided for by the contract. Carney v. Chillicothe Water & Light Company.—76-Mo. App. 532.—

(Mo. App. 1898.)—Though the schedule of meter rates in a contract between a City and a Water Company is introduced by calling it a table of annual rates, and the rates per quantity decrease as the quantity increases, the price to be paid by the consumer will be determined by his average daily consumption based on the amount used for a month, and not by the consumption for a whole year, such being the evident intent of the parties.—Carney v. Chillicothe Water & Light Co. —76-Mo. App. 532.—

26.—In case of non-payment of water rent or violations of these rules and regulations, the water will be shut off until the matter is satisfactorily settled, and a fee bill of $1.00 collected for turning on water. All water bills are payable quarterly in advance, on the first of January, the first of April, the first of July, and the first of October of each year, except lawn sprinkling, which is payable by the season in advance. Meter bills are due on the first of each month for water used during the preceding month.

27.—Water rates not paid ten days after they are due, the supply will be withdrawn, and water will not be turned on the premises either for the present or any subsequent occupant, until all arrearages and the sum of $1.00 is paid for extra services. Where measured

water is supplied the Company will require a deposit in advance, or security sufficient to insure the full payment of bills when due.

Here the writer wishes to call attention to the error made by most water companies and water boards, namely, calling this charge a penalty instead of a charge for labor performed. The Courts have sustained Water Companies and Water Departments in a reasonable charge for turning off and on water for non-payment and will continue so to do.

(Pa. Com. Pl. 1899).—A private incorporated water company will not be enjoined from cutting off water supply, in accordance with its rules, in order to enforce payment of water rent.—Smith v. Scranton Gas & Water Co. 5 Lack. Leg. N. 235.—

(Mass. 1898.)—In the absence of a statute making an unpaid water bill a charge upon the land, a water company cannot refuse to supply water to one tendering the price in advance, on account of an unpaid bill of a previous occupant of the premises.—Turner v. Revere Water Co, 50 N. E. 634.—

(Tenn. Ch. App. 1899.)—A water company's rule that consumers shall pay three months in advance for water supply, is reasonable.—Harbison v. Knoxville Water Co. 53 S. W. 993—.

28.—The Company reserves the right to use any of the service cocks when necessary for its own protection. The inspector or other authorized agent of the Company shall have access at all reasonable hours to the premises taking water to see that these rules are observed or to make any examination of plumbing or water fixtures, and no other person shall have control of the corporation cock at the main and the service cock at the curbstone.

29.—No person or persons, other than those designated by the Chief of the Fire Department, and those especially authorized by the City of ——— shall open any of the fire hydrants or attempt to draw water from the same or in any manner injure or molest any of said hydrants, and any person violating any of the provi-

sions of this rule will be prosecuted under the ordinances of the City of ————.

30.—The right is reserved to amend or add to these Rules and Regulations when deemed necessary, and it is expressly stipulated by the Water Company, that no claims shall be made against them or the City of ——— by reason of the breaking of any service pipes, or service cocks, or accidental failure in supply of water.

FREE WATER.

This has been a source of contention between Municipalities and Water Boards, as well as between Water Companies and Municipalities. A number of decisions have been handed down on this question, and in the majority of cases have been favorable to the Water Companies or Water Boards, as will be noted by the following:—

(N. Y. Sup. 1898.)—The charter of the City of Brooklyn Title 22, Section 33, Providing, that the several hospitals, orphan asylums and all other charitable and benevolent corporations are exempt from payment of water, is to be construed as being limited to the class of institutions specifically named or similar thereto, and hence, the Young Men's Christian Association is not exempt.—People v. Willis, 52 N. Y. S 739—.

(Ohio C. C. 1900).—Under a franchise granted to a Water Works Company stipulating that grantee "shall furnish free of charge all the water needed for use in the churches" such company may be required to furnish free of charge, the water necessary to operate a motor to furnish power to a pipe organ in the church, although at the time the franchise was granted, such motors, while used elsewhere, were not in use in any of the cities granting the franchise. Methodist Episcopal Church & Society, v. Astabula Water Company, 10 O. C. D. 648.—

(N. M. 1898.)—The Water Supply Company of Albuquerque agreed to furnish the City of Albuquerque with 12,000,000 gallons of water every six months for "City Purposes," to be used as the City Council might

direct. Held, that it is not a "City Purpose" to furnish water to the Board of Education, for the use of public schools, and upon the refusal of said board to pay for such water, injunction will not lie to prevent the Water Company from shutting off the Water from the schools. Water Supply Company, of Albuquerque v. City of Albuquerque—54 P. 969 January Digest.

Also, a Wisconsin Court has held that a church is only entitled to water for sanitary purposes, and is not entitled to water for driving a pipe organ, although the free water clause reads the same as in the Brooklyn case.

FIXING OF RATES.

This has always been a troublesome question, some States having a commission to fix water rates, others empowering City Councils to fix rates.

The Courts have frequently passed on this question and have in all cases held to the well known principle that the seller is entitled to a fair price for the service rendered, based on a fair valuation of the plant, maintenance, operating expenses, depreciation, and a fair profit on the service rendered.

(U. S. C. C. 1898).—A Board of Supervisors, acting under St. Cal. 1885, P. 95, which authorizes in a petition to fix water rates to be charged to consumers outside of cities and towns, and requires it in so doing, to ascertain the value of the distributing system, and the reasonable expenses of its management and operation, and to fix such rates that the net annual receipts and profits to the owners, shall not be less than six per cent. on the value of the property actually used and useful to the appropriation and furnishing of such water, and has no power to determine as a matter of law under the contracts between a Water Company and its consumers the latter are required to pay only such rates as will pay the expense of maintaining and operating the system without providing for making good the depreciation of the plant, or any profit to the owners, and

to fix rates upon that basis. San Diego Land & Town Co. v. Jasper 89 F 274—.

(Ill 1899.)—Under Act April 9, 1872, authorizing cities where water works are constructed by an incorporated company to contract with such company for a supply of water for a period not exceeding 30 years; and Act April 10, 1872, providing that a city council shall have power to provide for a supply of water, and authorizing any person or private corporation to construct and maintain water works, "at such rates as may be fixed by ordinance, and for a period not exceeding 30 years,"—there was reserved to the City Council the power to fix by ordinance at such figures as would be fair and reasonable from time to time, the rates for water furnished inhabitants and the City by such a Company.—City of Danville v. Danville Water Company, 53, N. E. 118,178,Ill. 299, P. 420.

(U. S. 1899)—Courts will not interfere with the collection of rates established under legislative sanction, unless they are so plainly and palpably unreasonable as to make their enforcement equivalent to the taking of property for public use without such compensation as, under all the circumstances, is just, both to the owner and the public.—Decree—(C. C. 1896) 74 F 79, affirmed.—San Diego Land and Town Company v. City of National City 19 S. Ct. 804.—

(Ill. 1899.)—Under the general incorporation act (1 Starr & C. Ann, st) (2nd Ed.) p 1006, section 9, of which provides that the general assembly may prescribe such regulations for corporations formed under the act as may be deemed advisable, and that such regulations shall be binding on such corporations, the legislature has power to regulate the rates at which water shall be supplied by a Water Company formed under the act.—City of Danville v. Danville Water Company, 54 N. E. 224, 180, 235.—

A number of others could be quoted but all bear out the above principle.

While the writer has been preparing this paper, attention has been called to a recent decision wherein a

water company is denied the right to make a charge for automatic sprinkler protection. The case is as follows:—

The Water Board of St. Paul attempted to enforce the payment of $20.39 a month against Gordon & Ferguson, for January, February and March, for furnishing City water to the plaintiff's automatic sprinkler, and threatened to shut off the water from the plaintiff unless the bill was paid.

The Court found, that the device had been demonstrated to be of great value in extinguishing and preventing fires; that said device had largely reduced the rates of fire insurance on buildings where same is used; that the annual savings for fire insurance to owners of said buildings and to plaintiff, is many times greater than the charge made by the defendants, and has largely reduced the cost and expense of defendants in furnishing fire protection to said City; that if the board should sever its water connections with the firm it would cause the firm irreparable injury; that the plaintiff has paid defendants for other water connections at regular meter rates, $4.60 a month, for January, February and March, and that the board's rule fixing charges were not based on any estimate of water used or to be used, in said sprinkler system, but were fixed by said board arbitrarily and without regard to consumption of water in said system. Said rules were adopted together as an entire plan, with the purpose and effect of compelling persons having automatic sprinkler systems, where they do not supply themselves with water upon the same premises for other purposes from the city water system, to pay an arbitrary sum for water which they do not use.

The writer cannot believe that this view of the case will be upheld by the higher Courts, first because as admitted in the decision, the service is a valuable one, in that it reduces insurance risks, thereby making a very great saving to the property owner as well as the tenant:—and, second, that it has been demonstrated that the said service is valuable, because it will pre-

vent fires, and third that it affects large savings in insurance premiums.

The writer cannot believe the Court took into consideration the large amount of money expended by the City in reserve machinery, storage and distribution system, for the purpose of taking care of the large connection, which are idle practically all the time, but must be adequately supplied when required and without a moment's notice.

The writer's wishes to acknowledge his indebtedness to the files of Water & Gas Review, Fire & Water Engineer, and the records of this Association, for valuable data in the preparation of this paper

THE CARE OF A MECHANICAL FILTER PLANT.

J. M. Diven.

A filtered water supply is not always an unmixed blessing, as its usefulness and safety depend largely upon how it is operated. This is ,in a measure, true of the slow sand filters as of the mechanical type. All filtration is "sand filtration," sand composing the actual filtering medium. In the slow sand filters the water goes on the beds in its natural state, in the other type with a previous preparation. But in both cases the sand is depended on for the actual work of filtering. The terms "slow" and "rapid" more nearly describe the two types.

In either type the efficiency depends on the condition in which the sand beds—the filtering material—is kept. Neither will or can give good results unless these beds are kept in proper condition.

To build a filter of any class and turn it over to cheap, unintelligent, inexperienced or careless men to operate, is bound to give poor results. And the chance is that the people will be worse off than they were before they had filtered water. Because, having a filter, they suppose the water to be all right, and use it freely, abandoning all the pre-filtration precautions. The house filters—of doubtful value at best—are thrown away, boiling of the drinking water is not kept up, and with all confidence they drink the water supplied through the splendid and expensive city filtration plant.

But this plant, if not properly cared for, can give them water nearly, if not quite, as bad as the raw water. Possibly conditions might arise which would give them even worse; foul filter beds make an excellent breeding ground for bacteria, one in which they might multiply much faster than in the raw water.

More, probably, depends on management, with the mechanical or rapid filters, than with the slow filters. The beds require more frequent cleaning, as they are called upon to do much more work for a given area

than those of the slow process. The preliminary preparation of the water must be carefully done; but neither plant should be intrusted to inefficient men to manage.

The manager of a mechanical filter plant must be properly trained for the work, if the plant is to give proper results. He must be a man of good judgment, able to meet and successfully contend with the varying conditions under which the filters work. For in most plants, the conditions do vary from day to day. A river from which the supply is drawn, may to-day be clear, bright and low in bacteria, to-morrow it may be swollen by heavy rains, high in color and turbidity, washing the refuse and filth form the banks, which have long been above the water line, consequently high in pathogenic bacteria. It is evident that the same processes will not cover both conditions; more coagulant must be added, the beds must be washed with greater frequency, when the water is muddy and foul. The man in charge must have the intelligence and experience to handle these changed conditions, and have the effluent of the filters just as good with the sudden flood waters to deal with, as with the comparatively clear and pure water of the low water stage.

No general fixed rules can be laid down for the care of filters; each case must be considered and studied by itself.

When the writer sees a man washing filters, watch in hand, giving just so much time to each, he drinks Apollinaris water while in that town, and thinks of the great risk that its people are running. This is following a rule, not using judgment, it is mechanical, not intelligent management, and it is, to say the least, risky.

The manager of a mechanical filtration plant must possess peculiar and varied qualifications, above all, he must be a man of good judgment. His position is of great importance, for in a measure, the health and lives of the people using the water, depend on him. To install a filtration plant for supplying a community with filtered water, and then turn it over to a $10.00 per week man to manage, is little, if any, short of criminal.

$10.00 per week can not be expected to purchase very much intelligence.

The man intrusted with the management of a mechanical filtration plant should be one trained for that work, he should first thoroughly understand the mechanism and all peculiarities of the particular plant and the conditions under which it is to work. He must be a man of some mechanical knowledge and training, that he may keep the mechanical part of the plant, pumps, coagulant feeding devices, washing machinery etc. always in good condition.

When installing a new filtration plant it would be well to select the man who is to manage it before construction is commenced. Then have him on the ground when the work is commenced, let him either be employed in some responsible position on the work, or as the inspector of it.

Being there and seeing the plant constructed, from start to finish, he would become thoroughly familiar with all the details of the plant, and be much better prepared to keep it all in thorough repair when completed than though he had gained his knowledge of it from drawings and descriptions. He would know, and understand, all the workings of the filters, and, so, be better prepared to operate them, having a more thorough understanding of their construction and the reasons therefor, of just how each part performed its work and why it was constructed as it was.

He must have some knowledge of water analysis, and should have some of bacteriology, in order to know at all times that the filters are doing their work well. Mechanical filters using sulphate of alumina as a coagulant require certain conditions that must be met, if the work is to be satisfactory. There must be present in the raw water, a certain amount of alkalinity, natural or artificial, to decompose the sulphate of alumina; and it is very necessary that the manager of the plant should be able to make tests for alkalinity to know that that amount is present. For if the alkalinity is not pres-

ent, undecomposed sulphate of alumina will pass through the filters into the filtered water.

These tests should also be applied to the filtrate, to make sure that it is alkaline, not acid, acidity indicating that sulphate of alumina was present. He should also be able to make the log-wood tests for the presence of Aluminum—hydrate in the filtered water, as a check on the alkalinity test. For allowing it to pass the filters is a serious fault, because of the waste of coagulant as well as injury to the water.

The ability to make these tests are almost an absolute necessity. An "expert" though always desirable, is not absolutely necessary for constant attendance. But the expert chemist and bacteriologist should by all menas be employed in the designing of the plant and planning for its operation; and should be employed to make "expert" examinations as frequently as circumstances will permit; not less frequently than twice a year, if the water handled is of the dangerous or contaminated class and unless the regular attendant is sufficiently expert.

Almost every water filtered is in some respects different, requiring different handling and methods of treatment; each has its own peculiarities and must be made an individual study—it cannot be taken as a type or class. And with waters taken from running streams, the conditions are frequently changed, requiring good judgment and experience to meet them. And, with such waters where only infrequent expert work is available, it should be distributed over the seasons as much as possible, so that there may be expert attendance at as many of the varying stages of the water as possible, and under as many of the varying conditions,—winter, summer, high and low-water etc.

The careful study of the case in all its phases, by experts before the work of filtration is commenced is essential. Indeed this study should be made before the plant is designed; for filters that will be successful with one water, might be an absolute failure with another. But with a plant properly designed to meet all condi-

tions—the variaitons in the water etc.,—constant "expert attendance should not be necessary. Only intelligent, good judgment, reliability, and a knowledge of the few simple tests mentioned above should be necessary for the successful operation of a mechanical filter plant. But let me again emphasize that periodic examination—as frequently as may be—by an **EXPERT** is most desirable. This is true also of water supplies not filtered; so should not be considered as "a charge against" filtration or as a part of the expense thereof.

With few filters in operation, consequently few men employed in operation of them, it might be asked where the men of experinece and training are to be found. And this is at present rather a serious question. The only way now is to select the best men available and have them trained for the work. Let us take a man with the required mechanical knowledge, and such men are available, and have him trained to the other qualifications. To properly do this, the plant and the man selected, should be under the care of an experienced filtration expert, till the man has acquired the necessary knowledge to operate the plant alone. This is, of course expensive—but expense must not be **too much** considered in the installing of a filtration plant, its proper care is too important.

The filter manufacturers might assist us by giving men the proper training in their shops and while erecting and preparing filter plants for acceptance test.

Or our technical schools might establish courses in filtration management.

Such a course need not be long; it should consist of a study of the different types of filters, and of the machinery necessary to operate them, and of a course in water analysis—not a full course, such as is taken by the young man preparing for expert work—but a thorough knowledge of the things essential to the proper care of the mechanical filter plant. These items have been outlined above.

A bright young man, particularly one who has had some previous knowledge of machinery, should be able

to complete such a course in from one to two years—possibly less. It is not intended that he become an expert, only that he be qualified to operate a filtraton plant. It would be well if he were a stationary engineer to start with, for filter plants are frequently designed to be operated in connection with pumping plants. And pumping is required at most filter plants, even though not in direct connection with the regular pumping works.

As stated it is not "experts" that are wanted, only well prepared operators; men who are willing to accept positions paying from seventy-five dollars per month up. Men who would be classed with stationary engineers rather than with experts.

Our schools and colleges are producing experts but what is needed is men who are within the means of small towns and cities to employ, and yet who have the knowledge and ability to properly operate a small filtering system.

CONSTRUCTION

The type of filter best suited to the conditions having been determined upon, the details are not difficult. Expensive and ornamental buildings and machinery are not necessary; the simple and cheaper construction will do the work as well. The main point should be convenience for operating. Compactness is desirable, but future extensions should not be lost sight of, and should be planned for when the plant is designed. The more compact the arrangement, the easier the operation, as a rule.

The writer favors small units, for several reasons. The cost is a little more not much, but the advantages are enough to fully off-set this.

1st.—With small units, a less amount of the total capacity of the plant is out of service while filters are being washed; or when one or more of the units are undergoing repairs, and all machinery needs repairing at some time.

2nd.—With small units, the varying conditions of

demand can be better met. A small portion of the plant can be cut out at seasons of small demand, if found necessary, and at times it is.

3rd.—With small units the filters can be sterilized thoroughly, at proper intervals, without seriously crippling the plant.

4th.—With small units, where the clear water storage is restricted, extra units can be provided, to be used while washing, sterilizing or repairing.

The writer recommends that for plants under five million capacity per 24 hours, the individual units have a capacity of not over one-third million gallons each.

For a plant of 5,000,000 to 10,000,000 gallons units of not over 500,000 gallons each.

For plants over 10,000,000 gallons daily capacity somewhat larger units could be used. But they should in no case exceed 1,000,000 gallons each.

We will not go into such details as clear water storage capacity, controllers, loss of head gages, etc., as the intent of this paper is to deal with the management, not the construction.

But certain features of construction are so much a part of management that they cannot be entirely neglected.

Proper provision for thorough sterilization should be made, and the provision should be for hot sterilization—by steam. It should be so planned that the hot steam will reach every part of the apparatus with which the filtered or filtering water will come in contact. This is usually accomplished by making the effluent pipes and system the inlet for the steam.

As the open or gravity filter is now the most popular and in most cases, probably the best, we will consider it. It is with this type that the writer has had his experience, and which will be dealt with in this paper.

With steam sterilization, the writer found that the covering of the filters during the process greatly helped it—was in fact, almost a necessity—a certain necessity, if regard was had for the paint and varnish in the filter room.

A cover made of one-half inch boards—tongue and grooved—made double with a layer of asbestos paper between, was devised. This was made in four sections, for convenience in handling. After the cover was provided, it was found necessary to provide some means for the escape of the steam; this was accomplished by means of a 6 inch stove pipe, fitted to the cover and carried out through the transom of the clear story of the building. But this was a make shift, made necessary because the matter of sterilization was not properly provided for in the designing of the plant.

A pipe system of proper size should be provided over all open filters. This would not be expensive or difficult. A line of 4 inch or 6 inch wrought iron, light weight pipe, running horizontally over the filters, with Tees and down branches to each filter, and proper outlets at the ends of the pipe, or such other points as required or found convenient, through the roof, would be ample for the purpose. Such pipe line and branches could easily be arranged so as not to be in the way or mar the appearance of the room.

COAGULANT FEED.

This is the most important, the vital item; for on the proper and uniform feed of the coagulant depends more than any other item, the success of filtration by rapid filters.

In the writer's opinion this feed should always be by gravity. The strong solutions used have an injurious effect on metal pumps, causing frequent and expensive repairs. Also causing excessive "pump slippage," consequently uncertainty as to the amount being pumped.

With a gravity feed the working parts can be made of hard rubber, and lead, on which the solution has no action. A constant and absolutely uniform feed can be obtained in this way—giving more certain and satisfactory results.

Such feed apparatus is not expensive or difficult

of construction. The writer in extending a plant, constructed a "coagulant tower," adjoining the filter house and easily accessible from the working floor. In the top floor of this "tower" all the coagulating device was placed, the feed being by gravity. The lower floors were used for storage of coagulants, which were taken to the top floor by an elevator. This provided ample and very convenient storage.

The tower was easily reached from the working floor, and a sight feed was also located on this floor, so the working of the coagulant feed could be watched.

Compressed air was used for "agitating" or stirring the solutions—both lime and sulphate of alumina. The air was fed through a coil of lead pipe, drilled with small holes and placed in the bottom of the tanks. To insure that none of the solution should come in contact with any metal, except the lead, the pipes were carried up above the tops of the tanks, so that when the air was shut off the solution would not back up to the valves. This device allowed the use of iron pipe from the compressors to the tanks.

The "coagulant tower" proved a success, and a great advantage over the old system of pump feed; also a very considerable saving in the expense.

WASHING.

The second item in importance is washing. When to wash, how long to wash, what pressure of wash water is best. All these things must be worked out in each individual case, and must too, be left largely to the judgment of the manager or attendant.

It is however certain that the clock should not be the chief guide. The attendant must use his judgment, and by close watching determine when the filter beds are sufficiently cleansed. No rule can be established for this, no rules can be given except such as have been worked out by actual tests, under working conditions. The "wash" may be long with one condition of the raw water, short with another. Nor will the color of

the wash water always determine the stopping point. It is a matter of experience and judgment entirely.

One rule, perhaps, can be made; a freshly washed filter is never quite as efficient as after a short "run." The first water through the filtters after washing should, therefore, not be sent to the clear water basin, but should be allowed to run to waste, provision for which is usually made in mechanical filters.

Just how long this waste should continue, must be a matter of experiment in each case; a few minutes is usually sufficient. This rather emphasizes the advisability of an extra unit or two.

It also, is a strong reason for not washing all filters at the same time, making a general wash. I know this is much easier and requires less attendance. But believe better general and more uniform results will follow the washing of small portions of the plant at once. It being acknowledged that the freshly washed filter is not as efficient as after a short run—and I believe that this will be acknowledged by all—it is plain that the fewer units that are washed at a time, the less the falling off in quality of the filtrate. In a plant of ten units we will say that the efficiency is 20% less for the first ten minutes after washing. Now if only one unit is washed at a time the general deficiency will be only 1-10 of the 20% due to washing— or 2%, instead of the entire 20%, as it would be were they all washed at once.

With a sufficient number of extra units the reserve ones could be kept washed and put in service when others require washing. The freshly washed ones becoming the reserve, and being allowed to stand until the beds were thoroughly compacted, when the efficiency would again be up to the standard.

STERILIZATION.

To be effective the beds must be clean. It is true that the frequent washing keeps them in good- condition, but they occasionally require a thorough cleansing, more than can be done with agitation and reverse cur-

rent of waters. The best sterilization is unquestionably "hot" sterilization—heat being the most efficient sterilizer.

Soda-ash in proper quantities should be evenly distributed over the bed, after it has been drained. Then if it is an open filter, the covers put on and connection made with the exhaust pipe to carry off the surplus steam. Then turn on live steam from the bottom, so it will go through the collecting or drain pipes and so up through the beds. A long stem thermometer should be provided, long enough to have the bulb in the bed and the scale extend up through the cover, for convenience of reading.

The beds should be brought to the boiling point—212°F.—and maintained there for at least half an hour: two hours was the writers practice.

Then shut off the steam, remove the cover, turn on the wash water and start the agitators, loosening up the bed, and thoroughly wash it with filtered water. After this it will be well to let the bed stand with the water on it till compacted. And when filtering is commenced, let the first water through run to waste; this waste should be kept up somewhat longer than in the case of ordinary washing. Here again judgment, experience and the result of tests must determine the necessary length of time.

Sterilization can be overdone; it is not needed often. With a large plant a good plan it to make a practice of sterilizing one unit at given intervals, thus going over the entire plant in a certain space of time. Of course emergencies may arise to make more frequent or even general sterilization necessary; but under ordinary conditions, the regular rotation at stated intervals will be enough.

It is not the writer's intention to go into minute details of operation. As a general proposition these must be worked out in each individual case; the principal object of the paper is to impress the fact that filters will not operate themselves, and that they must have skilled management to do good work. Good men

must be employed to operate them, and such men cannot be had at laborers' wages. They must be skilled men, and will have to be paid at least, skilled mechanics wages.

The writer would also emphasize the importance of some school of training for such men, that the supply may equal the demand.

Filtration of Public Water supplies is fast coming into favor, and will soon be considered a necessity in a great many places; so the demand for men to operate them will rapidly increase. This is a promising field for young men, one that offers steady and pleasant employment at good wages—we will not raise it to a salaried position.

Filtration is desirable; is rapidly becoming necessary, and so it is and will be with skilled practical and intelligent operators.

DISCUSSION

MR. DIVEN: My intention in writing the paper was not to tell anybody how to operate a filter plant. If you will look over the paper you will see that among other things I said there that there is absolutely no rule which can be laid down for the operation of a filter plant. Every filter plant must be studied by itself, exactly as the doctor when going to visit a patient has to diagnose that particular case, and cannot go by any general rule. The principal point that I have aimed to emphasize is that a mechanical filter plant is something that requires careful and intelligent care, it is not a thing that can be built and left to run itself. A pipe system is built, and that is the last that is ever thought of it, that is, as Mr. Hill will tell us by and by in his paper, as long as it goes along all right, the water is good and the supply fairly good, it is let alone. The same way with a pumping engine. It might be better if it had better care, but it goes along for an average length of time and there is no great harm done. Infinite harm is done if the proper care is not given to a filter plant; in other words the people are thrown off their guard, they are told that they are going to get properly filtered and pure water, but if instead of that, through lack of care in the conduct of the plant in all its details, the water becomes as bad, or possibly worse than it was before, sickness is sure to result.

MR. CHESTER: The paper by Mr. Diven I read with considerable interest. It brought out some features in my own experience in the operating of filters, and impressed upon me one idea mentioned here which is not brought out there. The operation of the filter does require a great deal of knowledge. You may call it knowledge, or you may call it experience, but that knowledge, whether one or the other, is not always possessed by the ordinary engineer of a pumping station or the ordinary man that we can pick up at a reasonable salary. In the plants of the American Water Works & Guarantee Company, in which I was interested for a number of years, in our filter operations we employed a chemist who went from plant to plant and ob-

tained for us definite results, but we found after about a year of his work that while he knew a great deal about the operation of filters, and while he was at the several plants the filters were well operated, yet he was not imparting to the men who stayed there all the time a practical knowledge of how to operate the respective filter plants.

Although he was a good operator himself, he had not been a good teacher, and in one instance I found the filter beds badly caked, and on inquiry made as to why more force was not used in washing, the operator, who was the engineer of the plant, picked up a stick having a notch cut in it at a certain point, and said, "My instructions are to open the wash valve till the water rises to a point on that stick, and to wash so many minutes with the water at that rate." Notwithstanding that, the filter got very badly clogged with clay,—badly caked, which could have been prevented had he in washing increased the rate as necessity demanded. Well, there was not any chance to scold that fellow, but there was a good chance for a good heart to heart talk and instructions that should prevail in the future that the filter was to be washed hard enough to get it clean, but not hard enough to wash the sand over. There is always a medium. And with the young man who was teaching the filter operator we had another talk, and we worked this idea out with him, that his value in the future would consist largely in the amount of information that he was able to impart to the men around the different plants, instead of the amount of knowledge that he could carry himself, and it was surprising and gratifying how soon that young man made a large number of expert filter operators out of those men who had before been looked upon as simply valve twisters. They first made hardness determinations, and tests for free alum and lime, later on they took up bacteriological work, until out of the twenty-three filter plants operated by that company to-day there are over fifteen of them where the ordinary operators can make all the necessary tests for bacteria. Out of these, three or four men have become fairly expert chemists and bacteriologists, and who started right out from the little instruction that was originally given them, purchased books, studied the little

chemistry necessary; and I was proud to hear the name of W. E. Taylor, New Castle, read out here to-day as an applicant for membership. He was one of the three or four that have become real bacteriological and chemical filter experts. You who live in his vicinity, and need any instruction of that kind can feel safe to call upon him. Three years ago he knew nothing more about chemistry and bacteriology than the man in the moon. He was simply engineer at the New Castle pumping station. Having acquired a little knowledge, he had a thirst for more.

I believe that if every waterworks superintendent would go home from this convention with the conviction that he or his engineer, or his filter man, can with a little application work out all the necessary knowledge required to intelligently operate and determine the results he is obtaining from his filter plant, that he will have gained something in coming to this meeting. I know that by actual experience and from my own observation of a large number of plants.

THE PITOMETER AND WATER WORKS LOSSES.

Edward S. Cole.

One of the foremost problems in water works engineering today is *waste* which has grown to alarming proportions in many American cities already involving vast expenditures for unnecessary extensions of plant besides adding an ever increasing burden in cost of operation.

Let us briefly consider the nature of this Waste and means for its control.

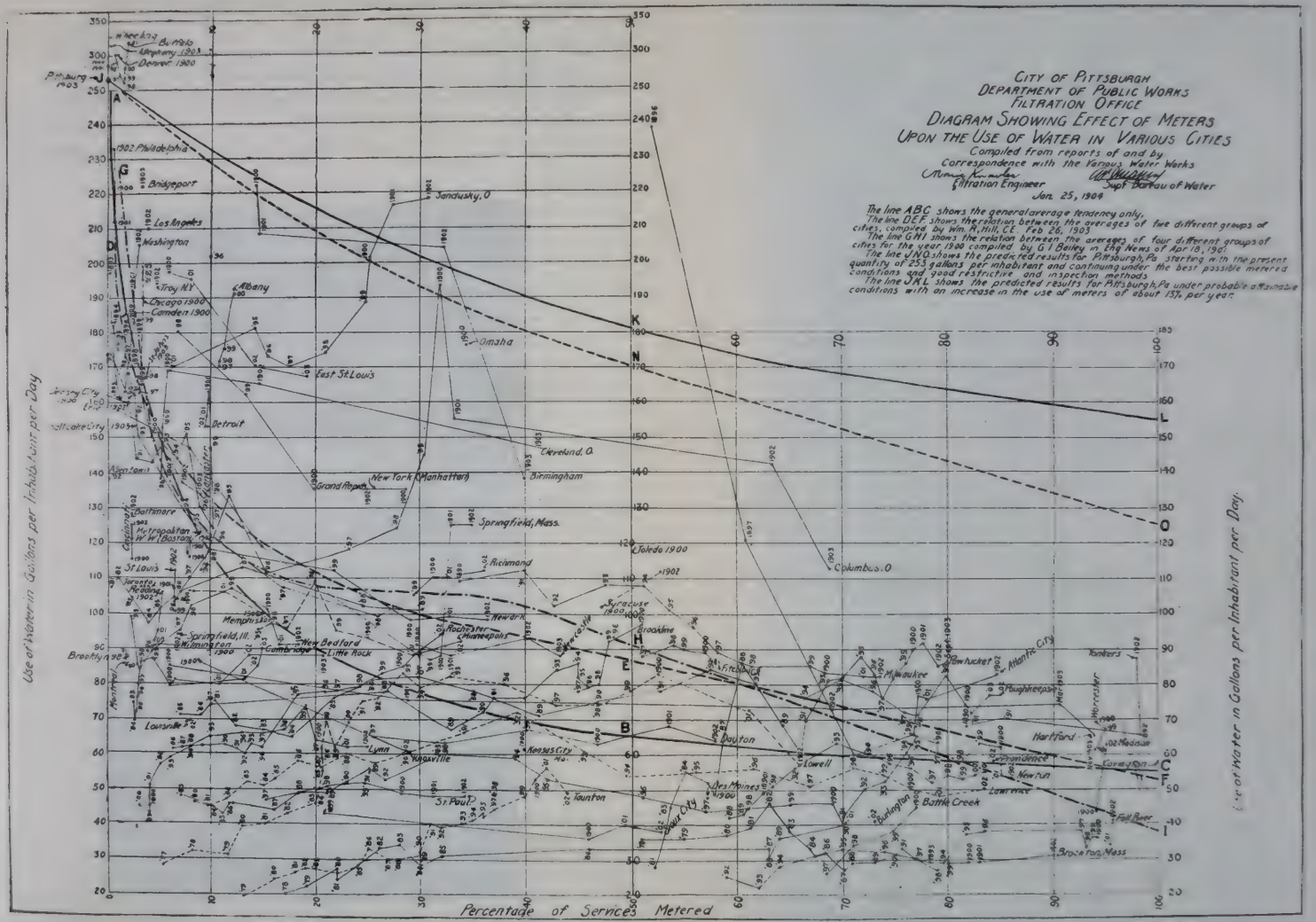
The ancient Romans struggled with a heavy loss of water from their costly aqueducts as we are told by Frontinus and water works men are still attacking the same old problem.

Among the effective instruments that are helpful in the study of waste, is the Pitot tube, which has greatly simplified the measurement of flow of water through the intricate network of our underground pipe systems.

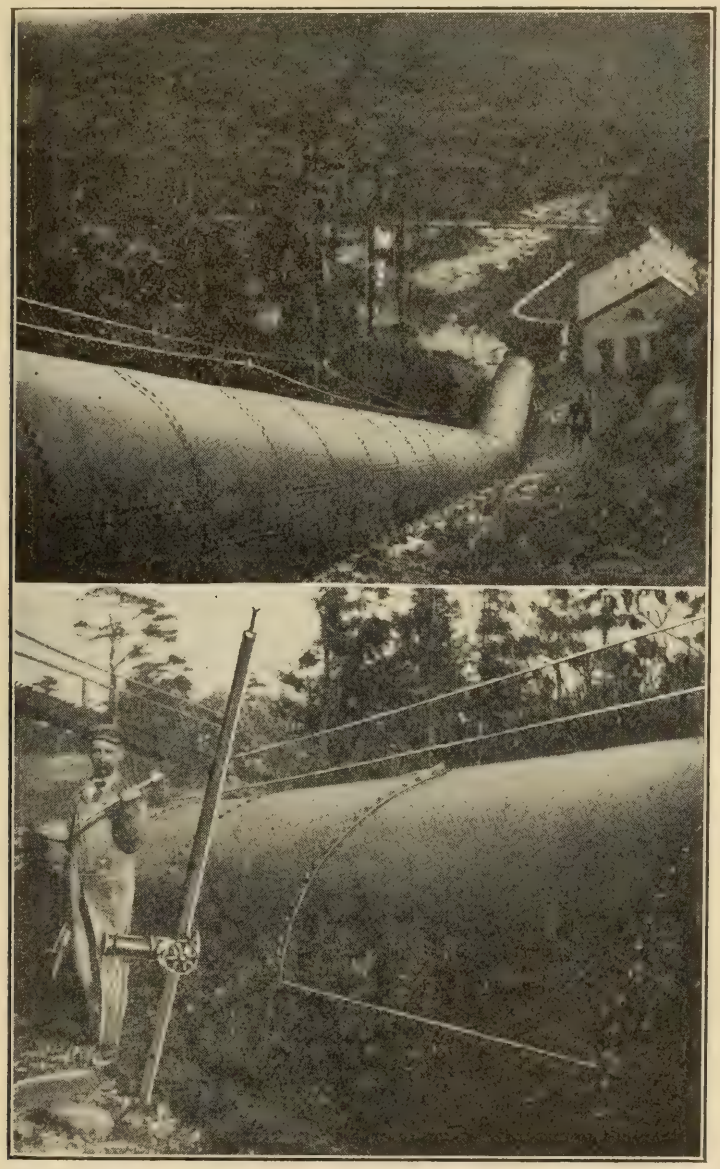
These distribution systems which are the most costly and vital part of a Water Works plant, consisting of a vast gridiron of cast iron mains, aggregating hundreds of miles in the case of our large cities with a total valuation of millions of dollars,—has received less scientific attention than the more conspicuous parts of a Water Works property; for example,— *Filtration* has benefited by the wonderful developments of sanitary science, and a century of steam engineering has produced the high duty *Pumping Engine,* but comparatively little has been done to improve the all important pipe system.

The Water Works manager has never had accurate information regarding the flow of water in the various parts of his pipe system without using expensive and cumbersome means. Costly extensions of mains have therefore been left to guess work and much money thrown away.

Analysis of consumption in districts has been well nigh out of the question because of the great cost of old methods for gauging the mains.


CITY OF PITTSBURGH
DEPARTMENT OF PUBLIC WORKS
FILTRATION OFFICE
DIAGRAM SHOWING EFFECT OF METERS
UPON THE USE OF WATER IN VARIOUS CITIES
Compiled from reports of and by
Correspondence with the Various Water Works
Filtration Engineer
Supt Bureau of Water
Jan. 25, 1904
The line ABC shows the general average tendency only.
The line DEF shows the relation between the averages of five different groups of cities, compiled by Wm. M. Hill, CE. Feb 26, 1903
The line GHI shows the relation between the averages of four different groups of cities for the year 1900 compiled by G. I. Bailey in the News of Apr 18, 1901
The late JNO shows the predicted results for Pittsburgh, Pa starting with the present quantity of 253 gallons per inhabitant and continuing under the best possible metered conditions and good restrictive and inspection methods
The line JKL shows the predicted results for Pittsburgh, Pa under probable attainable conditions with an increase in the use of meters of about 15% per year.
Use of Water in Gallons per Inhabitant per Day
Percentage of Services Metered
Pittsburg 1903
Wilkesbarre
Buffalo
Allegheny 1903
Denver 1900
Philadelphia
Bridgeport
Los Angeles
Washington
Troy N.Y.
Albany
Chicago 1900
Camden 1900
Sandusky, O
Omaha
East St. Louis
Detroit
Cleveland, O.
Birmingham
Grand Rapids
New York (Manhattan)
Springfield, Mass.
Toledo 1900
Columbus, O
Richmond
Newark
Syracuse 1900
Brookline
Fitchburg
Pawtucket
Milwaukee
Atlantic City
Yonkers
Worcester
Hartford
Providence
Newton
Lawrence
Battle Creek
Fall River
Brockton, Mass
Dayton
Lowell
Des Moines 1900
Sioux City
Kansas City Mo.
Kansas City
Lynn
Taunton
St. Paul
Memphis
Rochester
Minneapolis
New Bedford
Little Rock
Cambridge
Springfield, Ill.
Wilmington
Louisville
Toronto
Baltimore
Metropolitan Wks Boston
St. Louis
Allentown
Jersey City
Scranton
Reading
Harrisburg
Altoona
Lancaster
Johnstown
Wilkesbarre
Scranton
Reading
Harrisburg
Altoona
Lancaster
Johnstown

This lack of information is now unnecessary for with the portable Pitot tube, measurements of flow may be cheaply made at any point without loss of time, and there is no longer any excuse for permitting losses from the underground system to continue.



Pure water delivered under pressure through pipes which provide adequate fire capacity is by no means a cheap product as a few figures may show.

The actual cost of supplying one million gallons of water in many of our American works varies widely from about $20 in some of our large cities to $300 or more in the case of some small plants unfavorably situated. The average for twenty-two cities reported to the New England Water Works Association for 1904 was about $92 per million for operating expenses and interest on bonds. This list includes no city larger than Cleveland, Ohio, where the reported cost was about $23. In Chicago the cost of water has been estimated at $19 per million gallons, on the same basis. There, for example, the distribution system has 2,000 miles of mains from 4″ to 48″ diameter valued at $16,000,000, or one-half of the cost of the entire Chicago Water Works system which is placed at $32,000,000.

With the growing demand for pure water supplies involving vast expenditures for filtration works the cost of water is increasing. For example, the city of Philadelphia is now building filters to cost over $30,000,000, and the necessity of reducing waste is therefore keenly appreciated.

Broadly speaking, *waste* is not the generous or even lavish *use* of water by consumers—but rather refers to wilful and careless *misuse*—to the streams which run continually from faulty house fixtures and from leaky underground pipes. — but water works Losses include also the very serious problem of illegal *use* of water by large metered consumers generally for trade purposes—through "bye-passes" which rob the city of much needed revenue.

The slip of pumps whereby our water consumption statistics are falsified is responsible for more trouble than has been supposed, for although loss of action in the pumps causes no waste of water it nevertheless calls for additional pumping capacity at great expense and increases the fuel account.

Waste of water is *the* great evil in our American water works systems and its effect upon city finances is two-fold—(1). In the futile attempt to fill the "sieve" which our leaky systems resemble, large appropriations

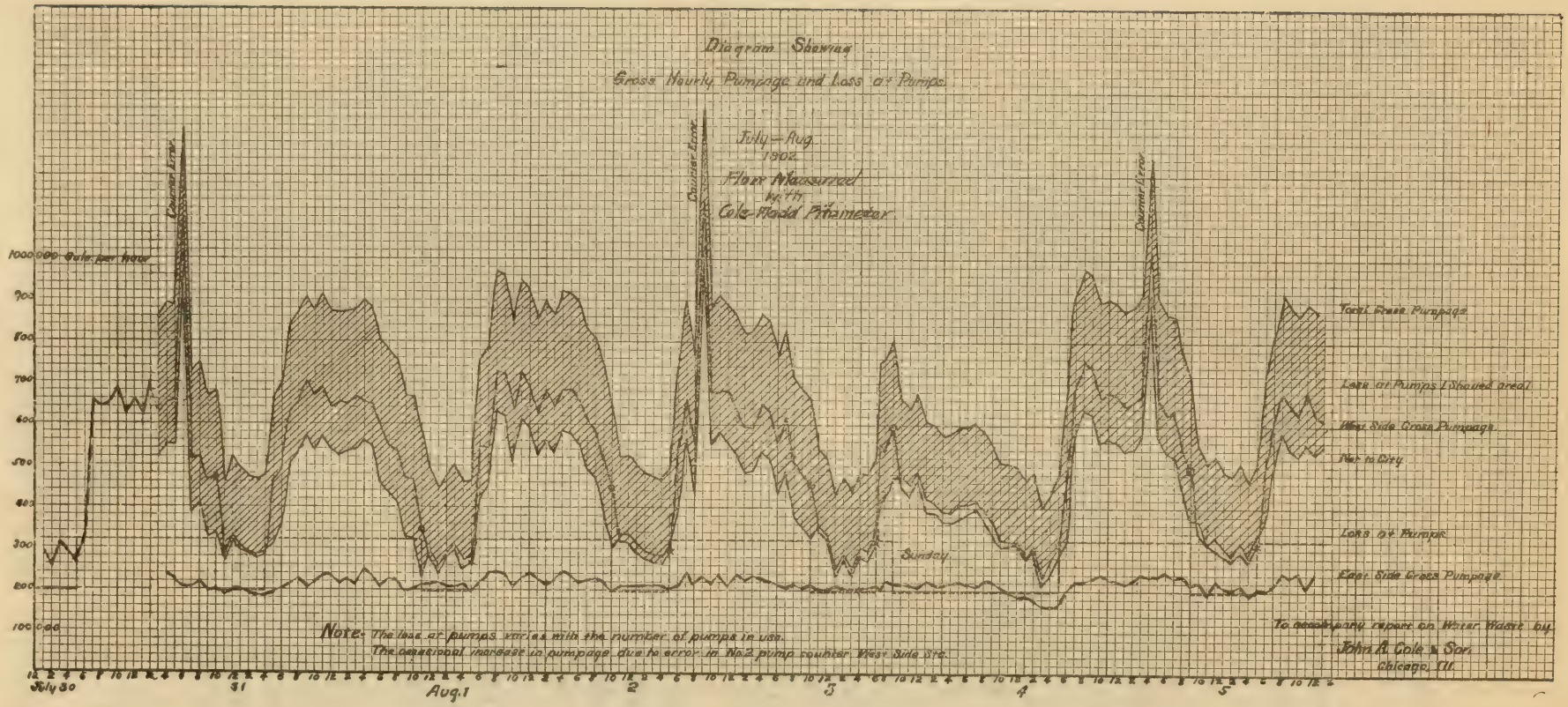


Diagram Showing
Gross Hourly Pumpage and Loss at Pumps
July – Aug.
1902.
Flow Measured
by 4th
Cole-Hadd Planimeter
Courier Error
Courier Error
Courier Error
1000000 Gals. per hour
900
800
700
600
500
400
300
200
100 0.0.
Total Gross Pumpage
Loss at Pumps (Shaded area)
West Side Gross Pumpage
Net to City
Loss at Pumps
East Side Gross Pumpage
Sunday
Note: The loss at pumps varies with the number of pumps in use.
The seasonal increase in pumpage due to error in No.2 pump counter West Side Sta.
To accompany report on Water Waste by
John A. Cole & Son
Chicago, Ill.
July 30
31
Aug. 1
2
3
4
5

are needed yearly to increase the pumping capacity,—and, (2) The pipe system needs continual reinforcement to maintain adequate fire service over and above the useless losses which drain its capacity.

Useless waste may amount to half the total supply of a city or even more,—for example.

In his report on Water Measurements, Mr. Dexter Brackett, C. E., concludes that half the total supply of the Metropolitan District is wasted, and a waste of one-half is evidently a serious matter. In New York City a recent report by Mr. Jas. H. Fuertes, C. E., places the waste and unaccounted for loss at 43% of the total supply, while Mr. J. R. Freeman, C. E., some years ago estimated the preventable waste in Manhattan at about 70%.

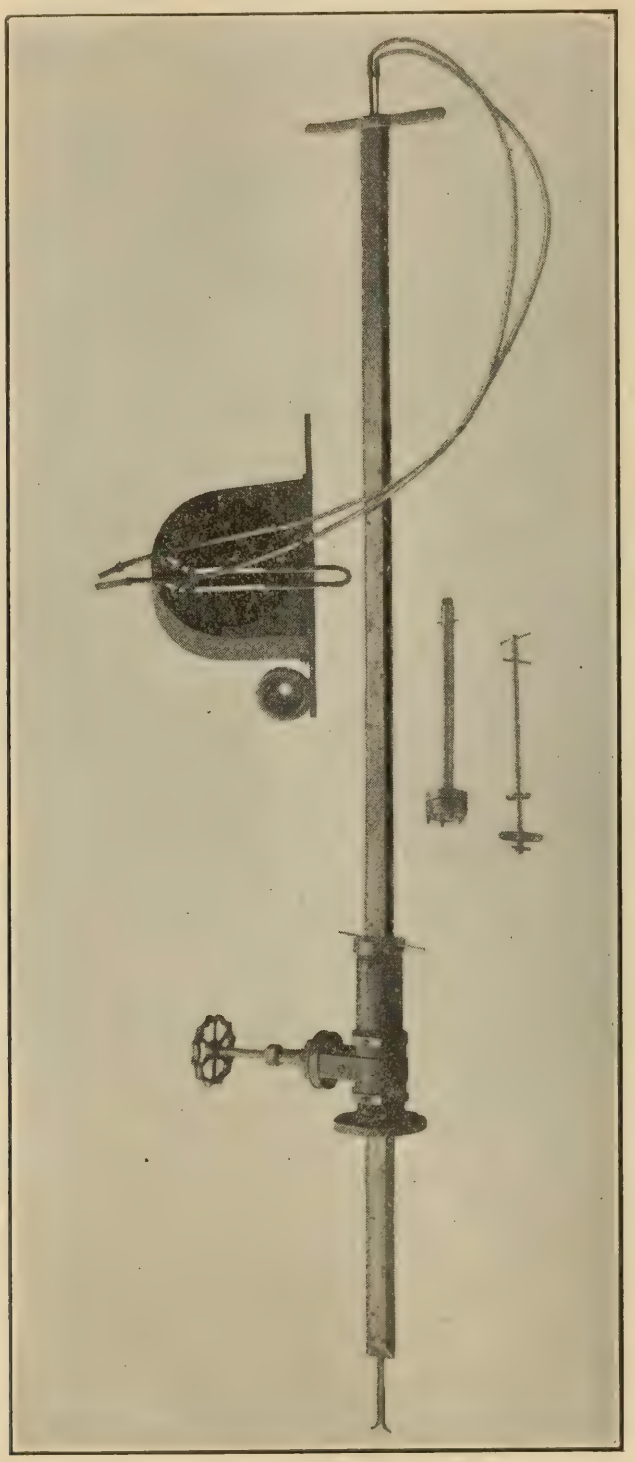
In a recent report on Water Waste in Chicago, Mr. John Ericson, C. E., puts the probable waste at 76% of the total pumpage and shows that $6,000,000 will be needed in the next ten years for tunnels and pumping plants alone, if the present wasteful conditions go on; Whereas, if means are taken to control these losses, this great outlay may be avoided, and at the same time a greater saving made in extensions to the distribution system, for, if one-half the supply is wasted the pumps must force twice as much water into the mains and since friction increases as the square of velocity this doubling of the consumption through waste creates three times more friction loss. The great cost of reinforcing a $16,000,000 pipe system does not need to be enlarged upon. Thus we see that the effect of waste on city finances *cannot* be ignored.

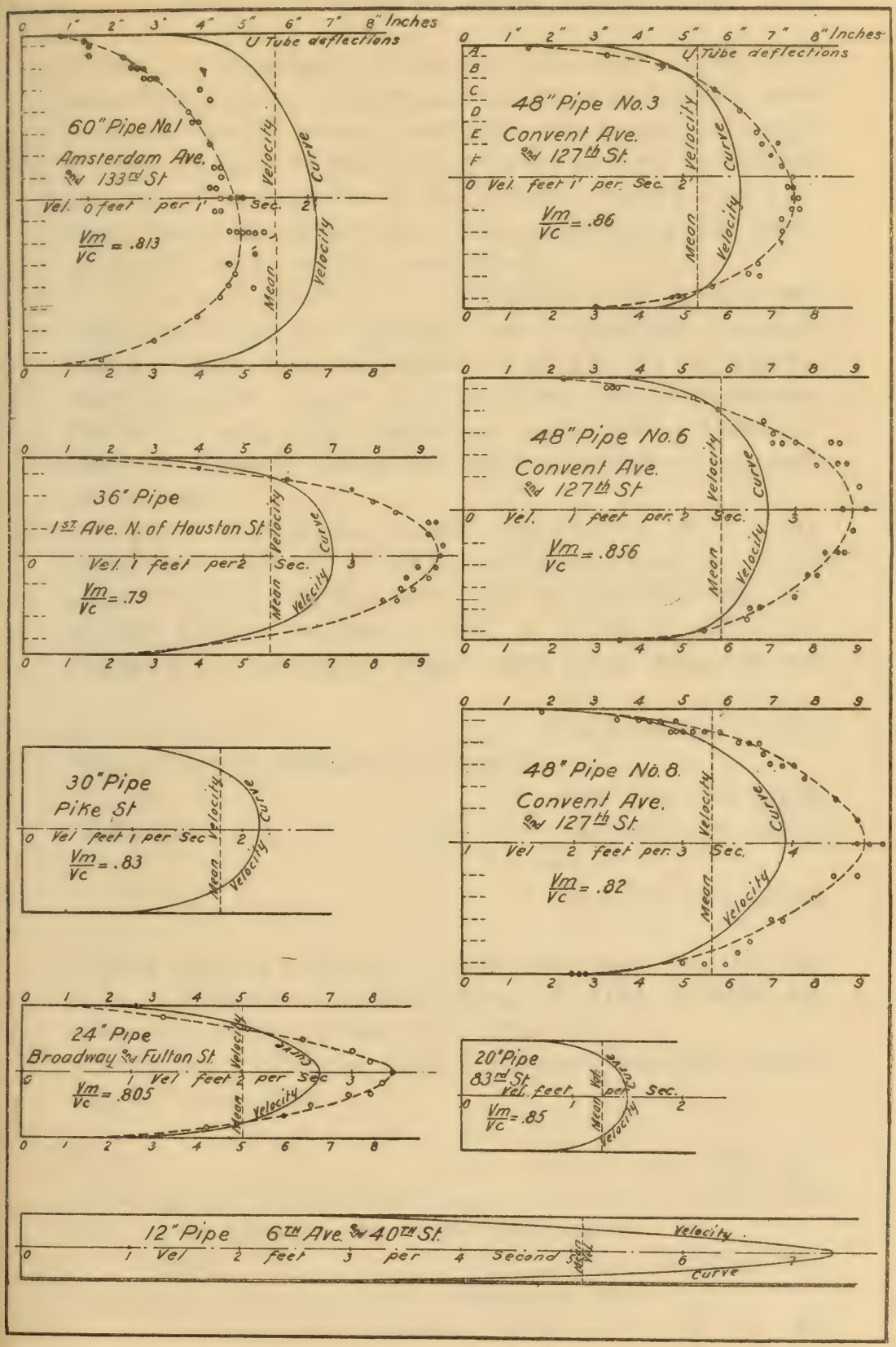
The principles of accurate accounting which are taken for granted in private business are peculiarly needed in Water Works management—but for lack of a cheap and portable meter they have as yet been scarcely applied in the country.

What is a fair and reasonable supply?

Let it be understood first of all that there can be no such thing as a standard per capita consumption by which cities may be compared one with the other.

Much of the controversy as to what constitutes an adequate water supply arises from lack of knowledge regarding the special requirements of different cities. It




0 1" 2" 3" 4" 5" 6" 7" 8" Inches
U Tube deflections
60" Pipe No.1
Amsterdam Ave.
and 133rd St
Vel. 0 feet per 1" Sec. 2
Vm/Vc = .813
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8
0 1" 2" 3" 4" 5" 6" 7" 8" Inches
U Tube deflections
A
B
C
D
E
F
48" Pipe No.3
Convent Ave.
and 127th St.
0 Vel. feet 1" per Sec. 2
Vm/Vc = .86
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8 9
36" Pipe
1st Ave. N. of Houston St.
0 Vel. 1 feet per 2 Sec. 3
Vm/Vc = .79
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9
48" Pipe No.6
Convent Ave.
and 127th St
0 Vel. 1 feet per 2 Sec. 3
Vm/Vc = .856
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8 9
30" Pipe
Pike St
0 Vel feet 1 per Sec 2
Vm/Vc = .83
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8 9
48" Pipe No.8.
Convent Ave.
and 127th St.
1 Vel 2 feet per 3 Sec. 4
Vm/Vc = .82
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8
24" Pipe
Broadway and Fulton St.
0 1 Vel feet 2 per Sec 3
Vm/Vc = .805
Velocity Curve
Mean Velocity
0 1 2 3 4 5 6 7 8
20" Pipe
83rd St
Vel. feet 1 per Sec. 2
0
Vm/Vc = .85
Velocity Curve
Mean Velocity
12" Pipe 6th Ave. and 40th St.
0 1 Vel 2 feet 3 per 4 Second 5 6 7
Velocity Curve
Mean Vel.

is folly to compare statistics of total per capita consumption without first separating trade and public uses from ordinary domestic demands. Then again the population per mile of main, the amount of lawn sprinkling per capita, and above all the relative luxury and personal habits of the several classes constituting the population of a city must be considered.

The very wasteful city of Buffalo, which has a per capita of over 300 gallons, has a metered consumption for trade purposes alone of 46 gallons per capita, more than the supply of Fall River for all purposes. Evidently such cities cannot be compared by their per capita consumption where they differ so widely in the trade use of water.

There is however, ample opportunity for a study of definite and carefully classified uses such as that made recently for the Metropolitan Water District (Boston) by Mr. Dexter Brackett, C. E., in which he gives the following analysis based largely upon actual measurement.

Domestic use,	25.0 gals. per capita
Manufacturing, mechanical and trade use	23.5 gals. per capita
Public use	7.0 gals. per capita
Total	55.5 gals. per capita

or less than 60 gallons daily for each man, woman and child. Whereas the Metropolitan District actually receives about 122 gallons per capita daily.

In other cities we have a reported total per capita ranging from that in

Buffalo	over 300
Pittsburg and Philadelphia	over 200
New York, Chicago, St. Louis and Boston, from	130 to 160
Providence, Worcester, Fall River and Milwaukee, largely metered cities,	40 to 80

Abroad one finds such cities as London, Liverpool, Manchester, Glasgow, etc., reporting from 30 to 60 gallons. But there we find that a policy of waste restriction has been highly developed which we will consider later.

In this wide range of supply to American cities, the reported figures are liable to be in error from unsuspected slippage in the pumps. One of the first discoveries to the credit of the pitometer was in a city of about 125,000 population which had been reporting 33% more water than was actually leaving the pumps.

Since this illuminating experience, similar tests made by the writer seem to indicate that leaky pumps are the rule rather than the exception, and a loss of from 25% to 50% is by no means unheard of even in engines of the highest type and largest size.

A wide variation in per capita consumption is due, as has been shown, to *trade use,* which will vary according as cities are largely residential or are devoted mainly to commerce and manufacture.

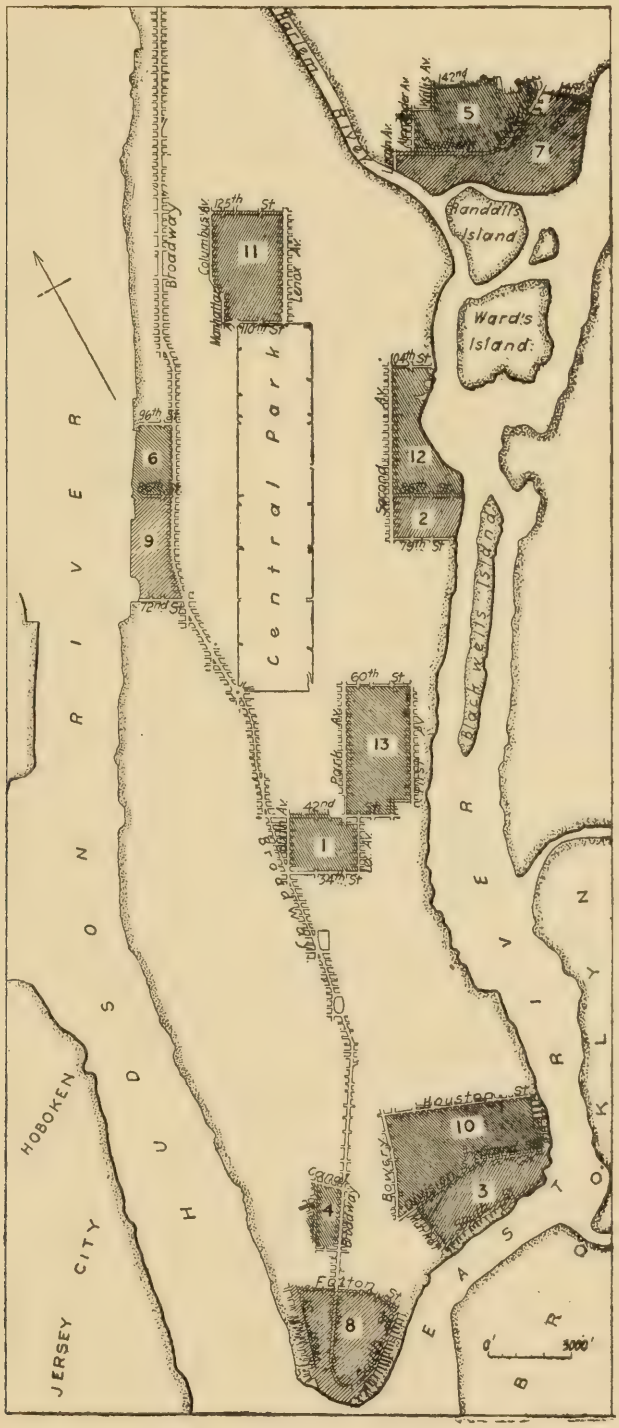
Public uses while but a comparatively small part of the total consumption, including the supply to public buildings, schools, hospitals, etc., are an important element. *Street sprinkling, sewer flushing and fire extinguishing* call for attention when attempting to reduce the supply to a per capita daily standard.

Domestic consumption varies, as already stated, according to the habits of the people and upon this point we are able to form a well based opinion as to what constitutes a reasonable allowance.

In Worcester, Mass., the total domestic use as shown by meters is 16.8 gallons varying from 12 gallons in the cheaper houses to 23 gallons in the best residence streets.

In Fall River the average class of dwellings generally with bath and water closet use about 8 gallons per capita daily, while in the most expensive houses the consumption is reported as 25 gallons. Boston apart-

ment houses varied from about 16 to 59 gallons per capita daily according to cost.



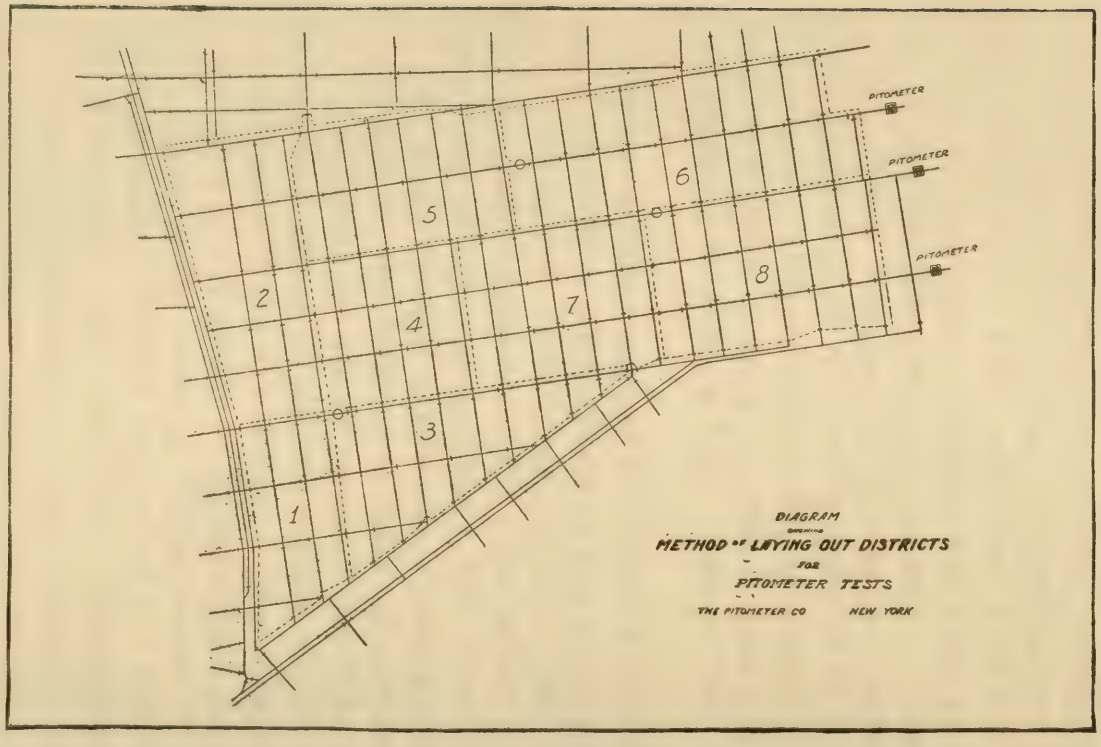
We should remember that these figures are for actual house requirements by meter measurements, and take no account of waste in the service pipe beyond the meter or in the street mains.

In Columbus, Ohio, a city with 125,000 population, there were in 1902, 8,000 meters, and among 2,000 of these taken at random from the books, 650 indicated a daily consumption of less than 15 gallons per capita. It follows then that in fully one-third of all the houses in this city the per capita use was less than 15 gallons per day, based on the meter statements. These 2,000 meters as a whole averaged 65 gallons per capita daily.

An examination of the hourly records of pumpage in cities is very convincing as to the existence of waste. The notable feature of such records is that the apparent consumption is always high even at the dead of night.

While we cannot judge of the relative wastefulness in various cities by a comparison of the per capita consumption, we find in reviewing statistics that the use of meters is always attended with a reduction of waste. An interesting diagram prepared by Mr. John R. Freeman, C. E., gives the per capita use of many cities and the percentage of taps metered in each. No better argument for the judicious use of meters should be needed for the excellent effect of placing meters on about 40% of the consumers is plainly shown. This diagram also shows that it is not economy to place meters upon more than about 40% of the premises taking water if all trade uses and the more wasteful consumers are included.

We should also note that these communities, having the largest percentage of taps metered and the smallest consumption are cities of moderate size. Here undoubtedly the demands are not as great as in the largest cities where, as a rule, less than 10 per cent of the taps are as yet metered. A meter system must always be supplemented by work for restricting losses in street mains and services beyond the reach of meters. There are many sources of waste of which the chief may be defined as follows:


PITOMETER
PITOMETER
PITOMETER
1
2
3
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7
8
DIAGRAM
SHOWING
METHOD OF LAYING OUT DISTRICTS
FOR
PITOMETER TESTS
THE PITOMETER CO NEW YORK

1. Defective plumbing in houses.

2. Wilful waste such as allowing water to run to prevent freezing, extravagant use of hose, etc.

3. Leaks beyond the consumer's premises in mains and service pipes.

4. Slip of pumps and careless station use.

5. Surreptitious uses not paid for.

1st. *Defective Plumbing* is a well known source of waste largely due to our American habit of permitting the use of cheap and inferior fixtures and the ordinary house meter certainly stands guard over it for a meter makes each householder his own inspector. The admirable English practice of requiring all fixtures to pass official inspection could, if adopted in this country, accomplish great results.

2d. Wilful waste undoubtedly exists. Many persons will let a stream of water run rather than to pay a plumber for making repairs and few realize how much a small stream will waste in twenty-four hours. An ordinary faucet on a first floor may run as much as 5,000 gallons a day.

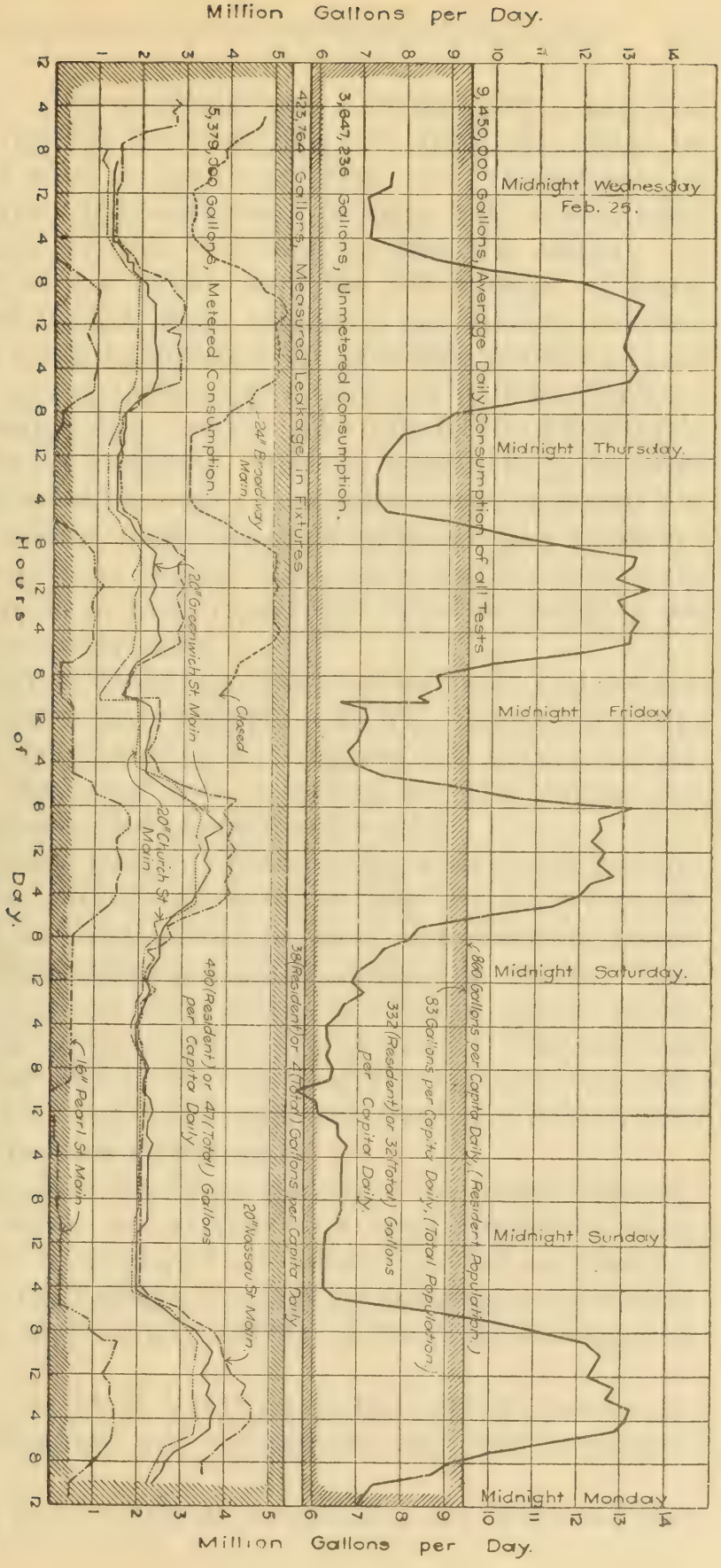
3d. Leaks beyond the reach of the house meter are undoubtedly larger than supposed as evidenced by recent tests and meter comparisons.

In a large number of cities having practically every tap metered, there is usually a discrepancy of from 30 to 50 per cent. between the total pumpage and the total meter registration. This unmistakable loss still remains after allowing for unmetered public uses, fires and for slip of pumps. The inevitable conclusion is that water is leaking underground from mains and services. In the 2,000 miles of water mains in Chicago for instance, there are fully one million joints of all sizes in mains alone and no one knows how many leaks from a mere drip to a heavy stream may be flowing into the sandy soil or nearby sewer without showing on the surface. A distribution system of this size will also have several hundred thousand small service pipes with an average length of perhaps 50 feet. These pipes are often of wrought iron which may soon be perforated by

corrosion. Leaky, broken and abandoned service pipes are responsible for much waste which because of a porous soil may not give warning at the surface.

Mains should certainly be tight and services sound. In an entirely new system, ranging in size from 4-inch to 16-inch cast-iron pipe, under 50 lbs. pressure, and before any service pipes were attached a test is reported showing a leakage of but one gallon per minute per mile of main. Such tests as this indicate that a well laid system may be practically tight.

Some have thought that a considerable allowance should be made for defects in meters but the large loss of water unaccounted for by total meter registration can hardly be caused by error in the meters themselves. In 1897, Mr. John A. Cole, C. E. had careful tests made of 1,064 meters in DesMoines, Ia., which had been in use from 1 to 15 years. Meters suspected of slip were mainly chosen, and the results showed an average loss of registration of only about 1 1-2 per cent.


Million Gallons per Day.
Hours of Day.
Midnight Wednesday Feb. 25.
Midnight Thursday.
Midnight Friday
Midnight Saturday.
Midnight Sunday
Midnight Monday
9,450,000 Gallons, Average Daily Consumption of all Tests
3,647,236 Gallons, Unmetered Consumption.
423,764 Gallons, Measured Leakage in Fixtures
5,379,000 Gallons, Metered Consumption.
24" Broadway Main
Closed
20" Greenwich St. Main
20" Church St.
20" Nassau St. Main
16" Pearl St. Main
860 Gallons per Capita Daily, (Resident Population.)
53 Gallons per Capita Daily, (Total Population.)
332 (Resident) or 32 (Total) Gallons per Capita Daily.
38 (Resident) or 4 (Total) Gallons per Capita Daily.
490 (Resident) or 47 (Total) Gallons per Capita Daily.
Million Gallons per Day.

4th. *Slip of Pumps and Careless Station use.*—All of the reported pumpage does not reach the mains because of what is known as "slip" and "station use" at the pumps. It is customary to make only a very small correction for this loss, and in fact the statistics of most cities are based upon the full amount of water displaced by the pump plungers, the almost universal method being to multiply the recorded strokes of each engine by the theoretical number of gallons displaced by its plungers per stroke. The only merit of this method lies in its simplicity. That it is liable to gross error has been found on many occasions when the actual discharge from a pump has been measured and compared with the counter record. Discrepancies of 25% to 40%, and more have been repeatedly found in pumping engines by pitometer tests.

This loss should be always determined and deducted from the reported supply to a city. Slip at the pumps is not only misleading but requires the same pump capacity, steam and fuel as though the full plunger displacement were discharged into the mains.

This slip leakage developed by wear of the plunger and valves permits the water to "slip" by, simply churning back and forth, doing no good, but absorbing power and valuable pumping capacity, which is worse. Such loss is of course more likely to become serious in the horizontal inside packed type of pump. The presence of sand or grit in the water will cause wear between plunger and ring, valve and seat, until in a few months the loss may be enormous.

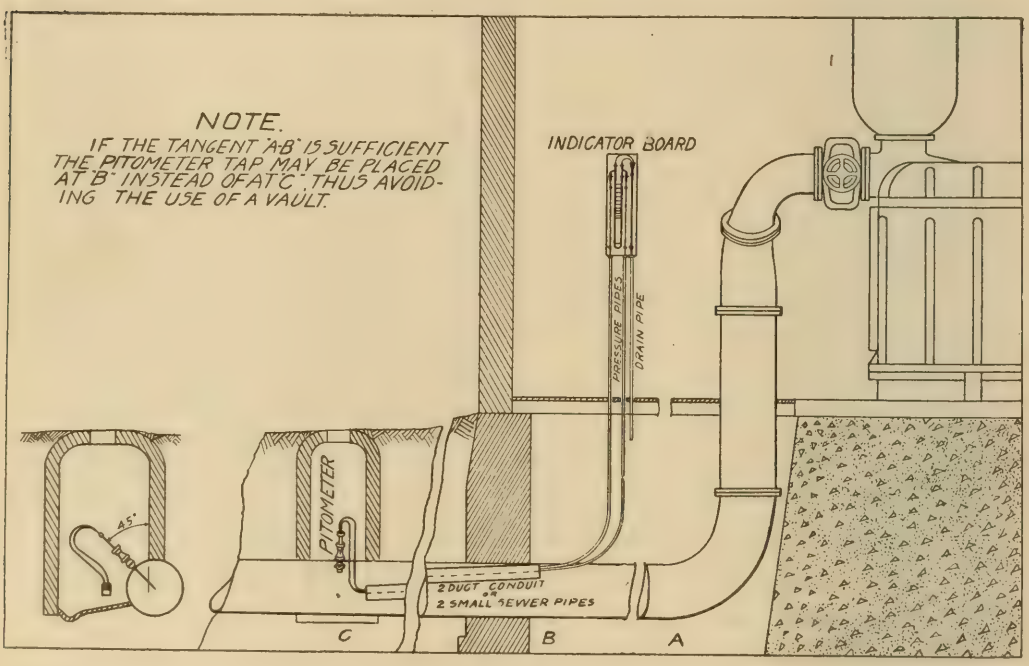
Electrolysis has been the cause of much deterioration of mains and services in a large number of cities. The leaks so produced are difficult to find and the full extent of the damage can only be discovered by making a careful and minute survey of the system street by street.

The extent of water waste has perhaps been sufficiently described and the remedy may now be considered.

In a water waste investigation a city is divided into

large districts, closing all the main gates but one, placing a recording waste meter on the inlet to the district, and keeping a record of the inflow. This total use in connection with the district population and the amount registered by the private meters will give a good idea of the wastefulness of the section taken as a whole, the rate of night use being most significant. In case the district shows a reasonable rate, it may be passed by thereby saving the expense and trouble of house to house inspection.

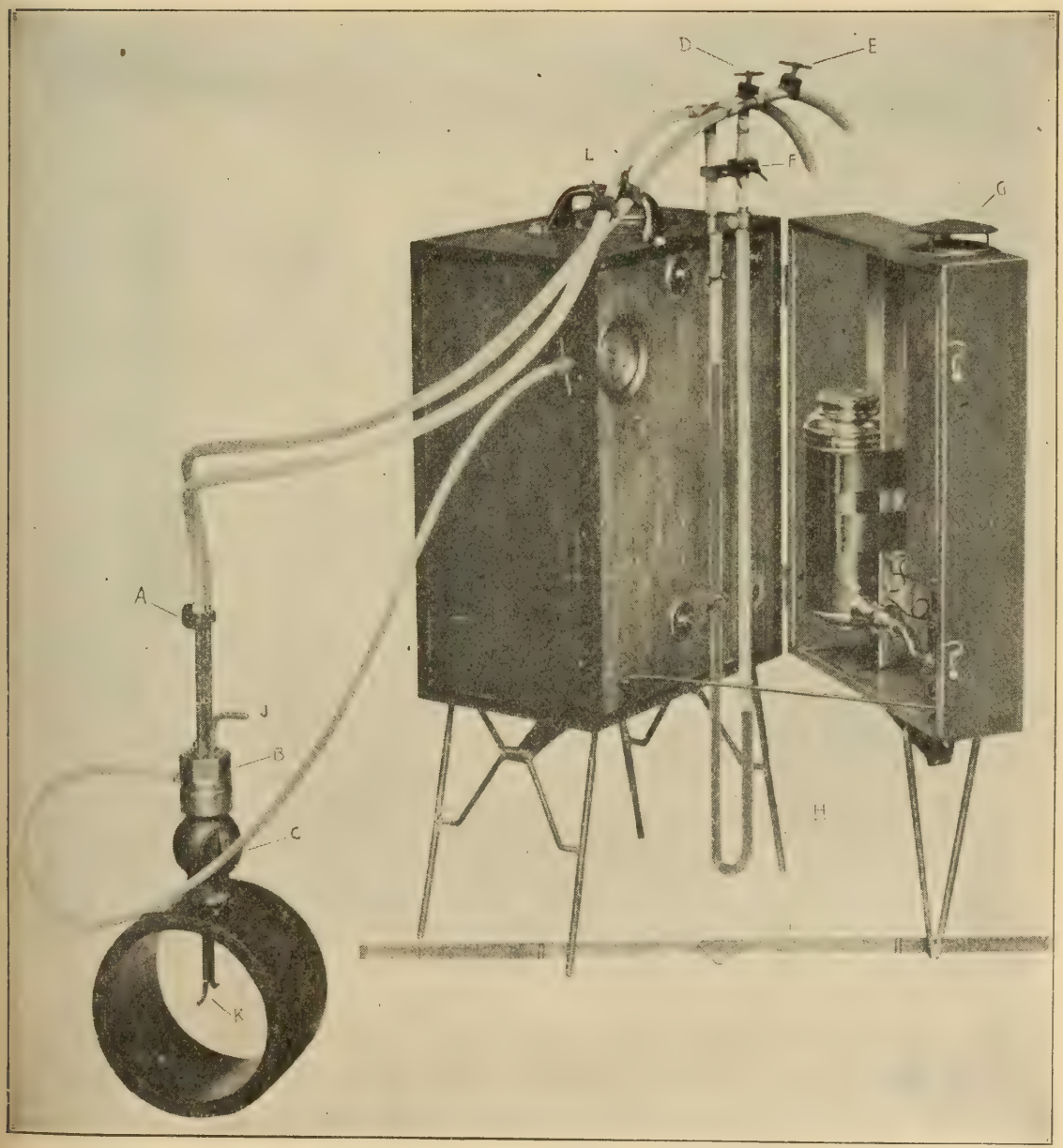
If, on the other hand an excessive per capita consumption in indicated the next step is to analyze the supply by streets, using the waste meter to record the



"drop" in flow as valves are closed one after another. Streets should not use water at the same rate per tap, and for this reason it is easy to find an unusual flow. When the waste has been localized within a few blocks a smaller section is inclosed by itself and supplied through its own waste meter.

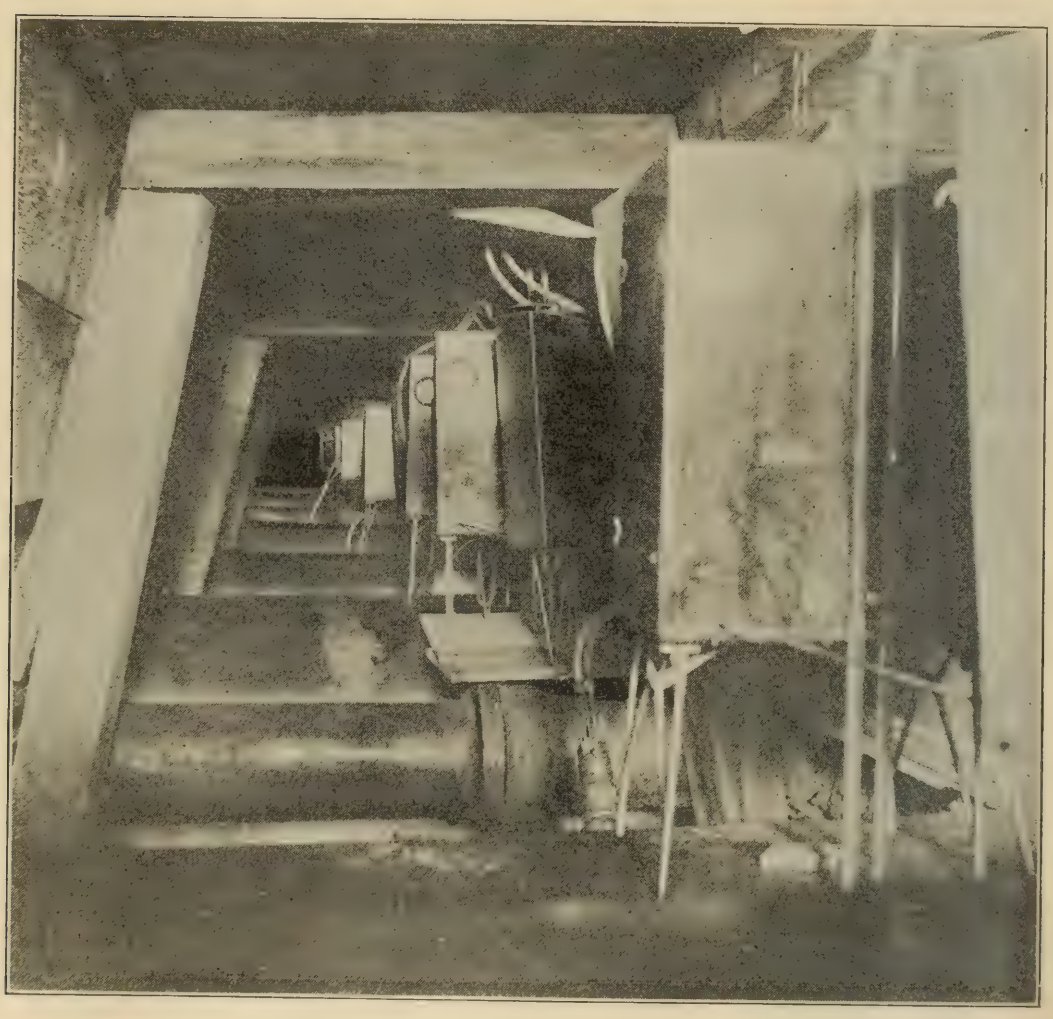
Then, if necessary, the curb cocks are closed one after another at night, the waste meter at the same

time continuously recording the rate of flow, so that when a house is reached which has a leaky service pipe or fixtures, the waste meter on the main will, on closing the curb cock, record a "drop" which is the rate of waste. In this way a record showing the condition of every house on the street is obtained and waste is located which can be further defined by house to house inspec-



tions. The waste meter record not only locates the loss on certain premises, but measures it exactly.

This American method by the use of Pitot tube is a development of the long established Deacon system, which, although still very much depended upon in England, has not proved popular in this country although for several years it was used in Boston with success.



Every large city should organize its own department for the systematic detection of waste according to some such plan as has been outlined. The work calls for the intelligent and skilled supervision of an engineer and must be persistently followed up for years, if need

be, to secure the final results. The time required to traverse a square mile depends on the number of waste meters employed and upon the physical condition of the pipe system. Several districts may be inspected at the same time under the direction of one competent head. Experience has amply proved the value of such work for its results are felt at once and the cost is repaid out of savings as the investigation proceeds.

This increase of income and the saving of expenditure for new pumps and mains will net millions of dollars to taxpayers. Purification works, which sooner or later are liable to be demanded in many of our large cities, can be built from funds so saved without becoming a burden. *Waste prevention and water purification* are now the order of the day and they ought to go hand in hand.

The form of recording Pitot tube described below was developed by the writer about ten years ago for use as a waste meter in an investigation at Terre Haute, Ind. The instrument proved to be accurate and efficient, and has since been adopted on important tests in our largest cities. Its fundamental principle was discovered by the French engineer Pitot, about the year 1732, and later improved by D'Arcy for use in open channels. Its application to water mains under pressure has been developed during recent years until the Pitot tube or "pitometer" may now be classed among the most useful and accurate engineering instruments.

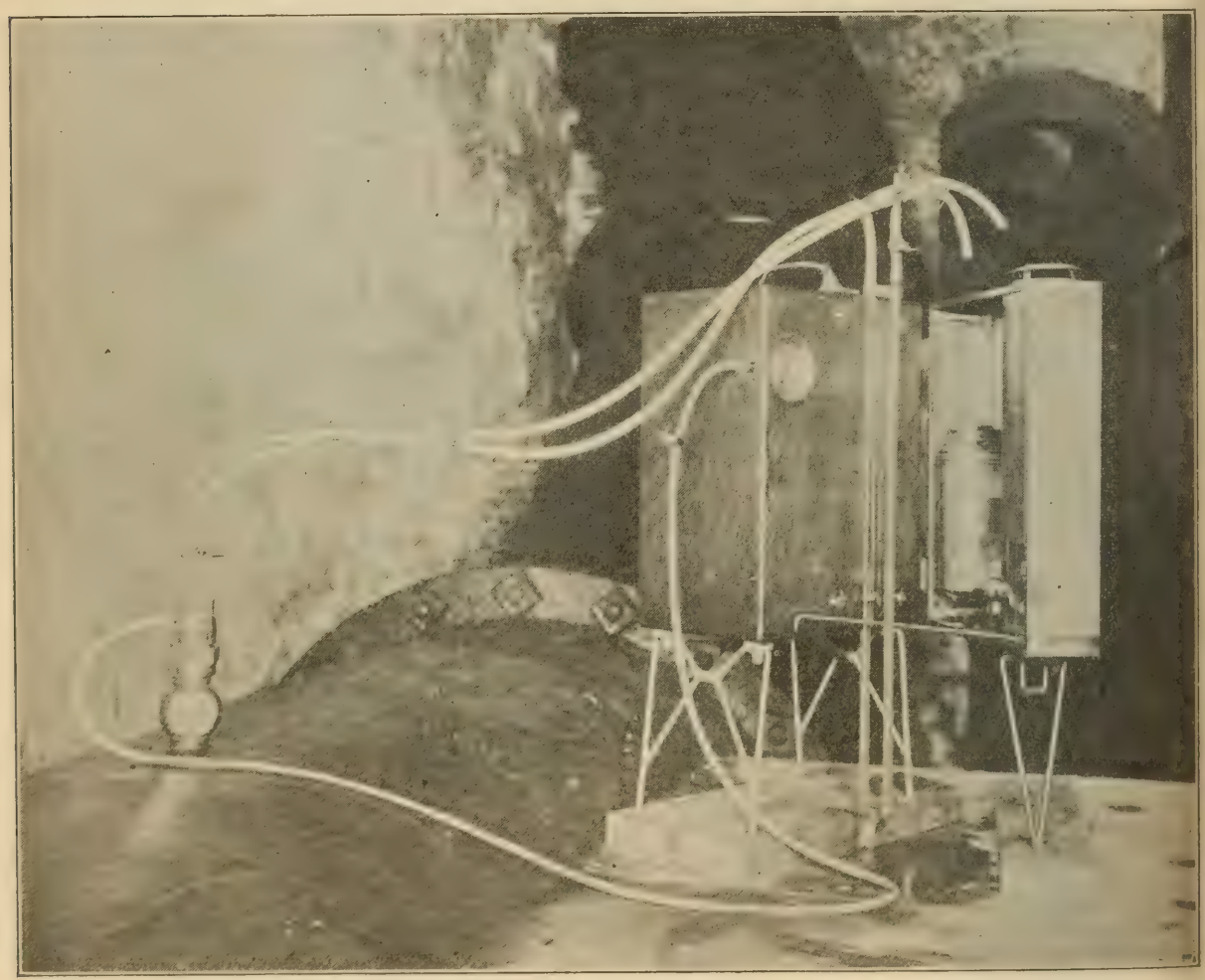
This instrument is primarily a rate meter, depending as it does upon the velocity of water within the main. It does not directly indicate the total discharge in cubic feet in a given time, as with displacement meters, but this elimination of the time element is necessary in a waste meter, for by the changes in rate we are able to study the effect of closing valves and service cocks in such an investigation as just described.

The instrument may be described as follows:

Two small tubes bent at their lower ends, with carefully formed orifices are held in a suitable cap which screws upon a standard 1-inch corporation cock through

which the tubes may be readily introduced into any main and as easily withdrawn. The rod-meter is the most recent development of the instrument by which the slender tubes are enclosed in an oval sheath which enables the meter to be introduced into the main from the surface of a city street through a "street connection" which is permanently set upon the main. Wherever street connections are set they are always available for use and by the application of the portable rod-meter the flow in the main can be at once ascertained.

Heavy cloth-insertion rubber tubing connects the orifice tubes with a long glass manometer or U-tube and blow-off cocks are provided to remove air from the



instrument. The U-tube is half filled with a mixture of carbon-tetrachloride and gasoline having a specific gravity of 1.25, and when in use the water from the pipe fills all the space in the U-tube and connections. The orifices are set to receive the maximum velocity within the main, which is usually near the center, and is indicated by the deflection in the manometer. This deflection, by virtue of the differential action of the water and the slightly heavier and insoluble liquid is just four times that due to the actual difference of water head on the orifices produced by the flowing stream. The current impignes directly on one orifice, but the other is turned down stream and gives something less than the static head within the main, thus increasing the difference of pressure produced. This difference is then multiplied in the U-tube, the result being that a low velocity within the pipe produces a readable deflection. Without this effect the Pitot tube would hardly indicate a velocity less than one foot per second, while the instrument described is reliable at velocities as low as 6 inches per second. At ordinary velocities the U-tube deflections may run up to 24 inches and therefore need not be read with any great nicety.

The photo-recorder consists of a portable box in which a drum carrying sensitized paper revolves before a fine vertical slit just in front of which is locked one leg of the U-tube, in such a position that the rays of light from an oil lamp will be partly intercepted on their way through the colored liquid in the lower half of the manometer. As the liquid rises and falls with the velocity in the pipe it will record a line or band of shade on the velox paper whose ordinates vary according to the well known formula:

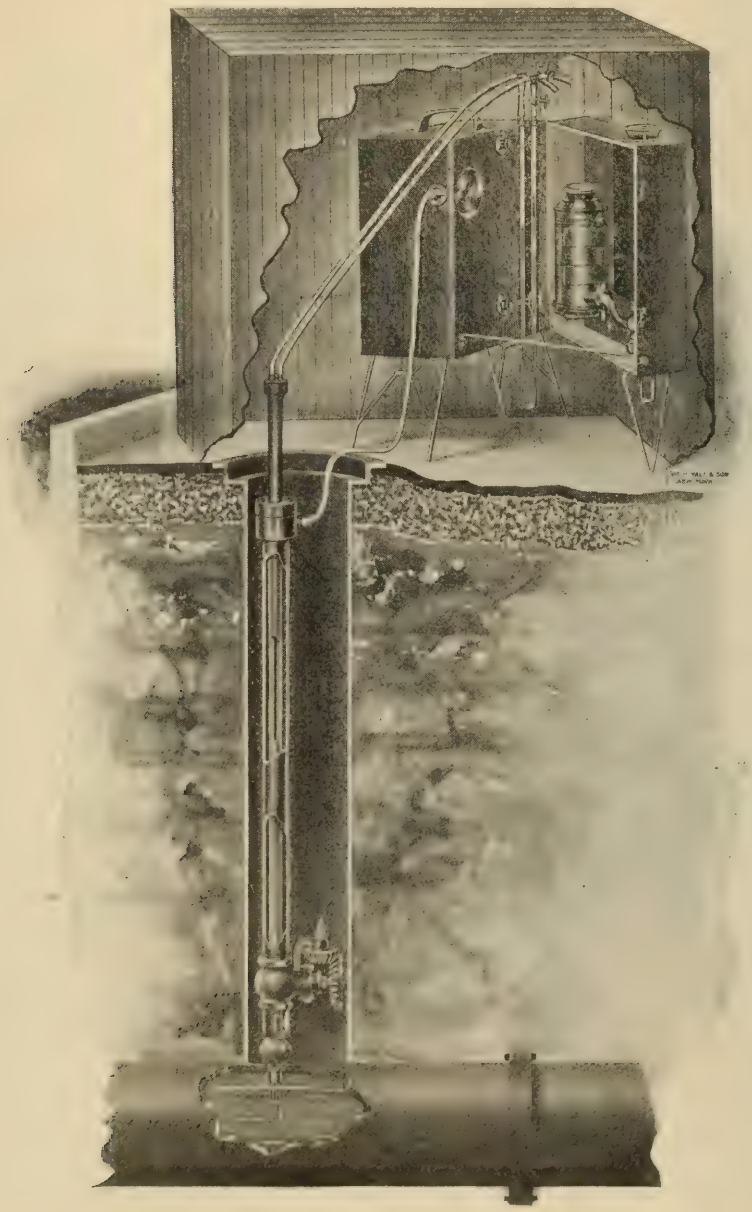
We have then:

$$V = c\sqrt{2\,g\,h}$$

in which "h" is one-quarter of the U-tube deflection in feet or half of the recorded ordinate on the paper. A photographic record is 18 inches long and 10

inches high. Autographic horizontal lines are formed by notches in the drum slit, spaced so as to correct for the angularity of the light and enable the true deflection to be readily taken from the diagram at any point.

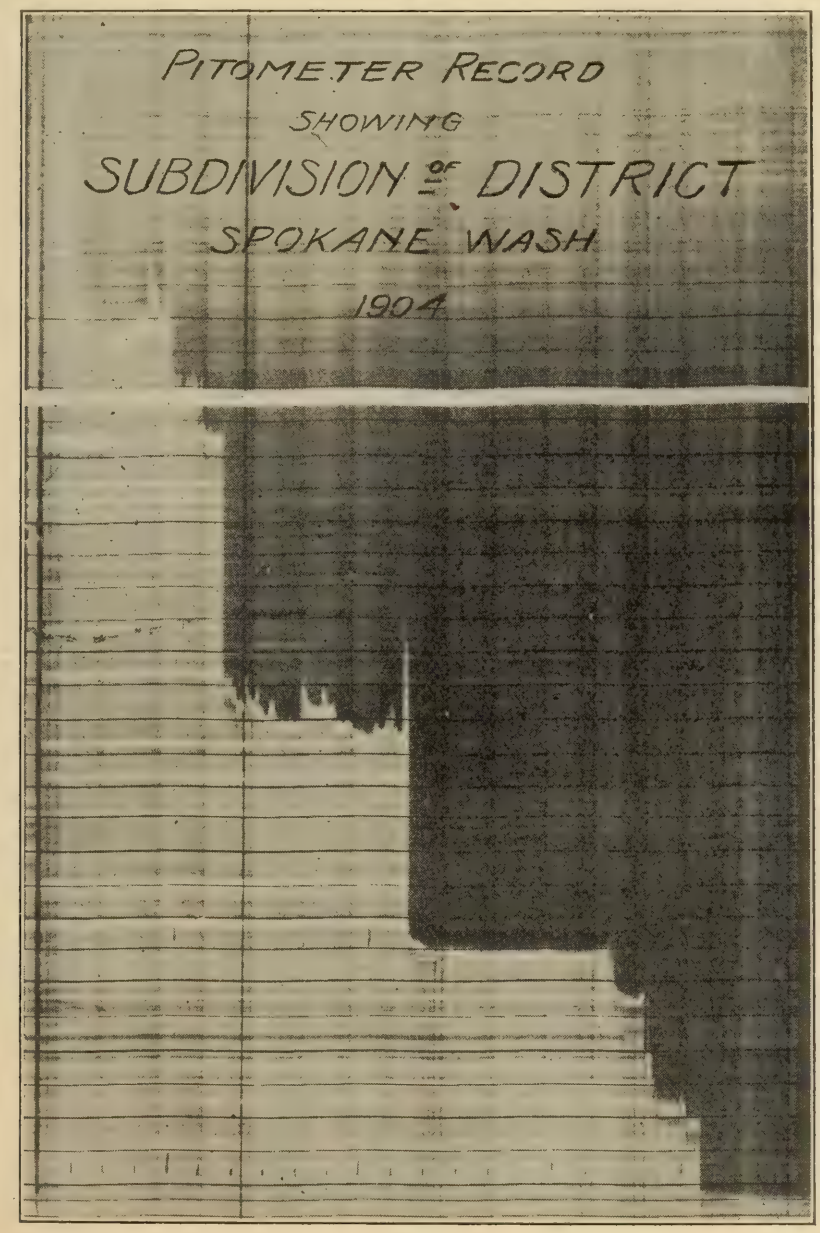
The accuracy of the pitometer has been established by many weir tests and also by calibration in open channels where the absolute velocities indicated by the instrument were compared with float measurements.



The calibration constant "c" of the orifices has thus been experimentally determined to be .80 in our formula

We have then $V = .8 \sqrt{\frac{2 g d}{4}} = 3.212 \sqrt{d}$

in which "d" is the U-tube deflection in feet. The actual velocity of the water is indicated in this way wherever the orifices may be placed within a pipe, and by com-



pletely traversing a given pipe section on one or two diameters the ratio of mean to maximum velocity is computed at some one rate of flow.

This ratio once determined for a given pipe holds good at all velocities. The orifices are permanently set to give the center maximum or velocity within the pipe, reading off the mean velocity and the discharge from a table prepared for the particular size of pipe and velocity ratio. This method leaves nothing uncertain. The mean velocity computed from a traverse of a pipe with the pitometer has been checked by careful weir measurement of the flow in pipes from 4″ to 72″ in diameter with close agreement. With careful use, discharge may be determined by the pitometer within 2 or 3 per cent. of the truth in pipes, an accuracy which is highly satisfactory in all practical hydraulic problems.

GREATER ECONOMY IN SMALL PUMPING PLANTS.

H. G. H. Tarr.

The Pumping Engine, more than any other form of engine, illustrates the gradual progress of steam from its most primitive form to the very highest achievement in the production of power.

From the introduction of the first pumping engine by Watt into the mines of Cornwall in 1778, when he contracted to substitute steam for veritable horse power, taking his pay from the saving in the cost of pumping, there has gone on a very slow but sure progress in economies in steam consumption. In this the pumping engine has always kept well in the lead.

This arises from several causes. First, they were built in larger units; the character of service was favorable; and, possibly more than anything else, municipal work did not restrict in original outlay, so the best engineering skill was brought into the design, and all that money could command into the execution.

For the first fifty years or so, after the introduction of the pumping engine by Watt, but little progress was made, and the old form of Cornish engine was adhered to in the larger plants. Early in the fifties the more enlightened engineers began to swing over to the crank and fly wheel type and it is in this, as applied to pumping engines, that the greatest economy in coal, generating steam, has been attained.

The writer has been closely indentified with this development for nearly half a century and it is interesting, to him, at least, to compare the engine of today with that of nearly fifty years ago.

In 1860, he was an apprentice boy in the old Woodruff and Beach Iron Works in Hartford, Connecticut. They were then building the first Brooklyn engine and it was to be, as it proved, the very best engine then known. Think of it, the contract was for an engine

to pump seven millions of gallons in 24 hours. It was to develope an economic duty of 70,000,000 foot pounds, something no engine had yet achieved.

It is interesting to note that this engine weighed 300 tons, the contract price was $127,000.00, and that it took three years to construct.

If you have a seven million gallon engine of the Brooklyn head to buy today you send out a letter to four or five builders and they will, by return mail, name you a price etc., which will be about as follows:

For a pumping engine of seven millions of gallons capacity in 24 hours we name you $20,000. We will guarantee you a duty of 145,000,000 foot pounds. This engine will weigh fifty tons, and, if the shops are not too full of work they will promise to deliver it in four months.

In substance, economic duty is doubled, the weight cut to one-fourth, the price to one sixth and the time say to one-fifth.

Taking another view of it, if you have one hundred and twenty-five thousand dollars appropriated for an engine, you get one having four times the capacity of the Brooklyn engine, and pumping two and one-half times the quantity of water with a ton of coal.

It is to be very greatly regretted that this wonderful progress in the development of pumping engines is limited to those of larger capacities, and what is known as the steam pump is about where it has stood from the invention of the duplex type, near the middle of the last century.

In our own association we have unfortunately forgotten our little brothers, and devoted all of our talent to discussing and applauding the designer and builder of the giant of today who shall exist upon less than the giant of last year, wholly forgetting that the greater total consumption is by the multitude of pigmies, who are now the same greedy coal devouring brutes as of fifty years ago.

Search our proceedings for twenty-five years back, and see what space we have devoted to the discussion

of bettering the condition of this, the most wasteful machine, the steam pump of smaller capacity. This is unfortunate, as in the aggregate, very much more water is moved, and infinitely more coal consumed by pumps, as they are distinguished, than by pumping engines.

So it is the purpose of the writer to urge a very thoughtful consideration of this subject, feeling that in no one direction can you, in your deliberations, do as much good to the poor brother who is struggling along on a large expense account and small consumption, as in suggesting a possible means of saving in his coal pile.

We will consider this subject wholly in its relation to Water Works Plants but let us not be oblivious to the fact that, within this class of machine, the Water Works service of the country is but an infinitesimal amount compared to the whole pumpage.

To illustrate the relative total consumption of coal by what we have designated as pumps to that of pumping engines in Water Works, let us take some one State and see what proportion of the plants are of this, the small class, to which this condition must apply.

We will select Iowa, a State of extreme prosperity, and one representing probably, as well as any, the average condition throughout the contitnent.

Iowa has, from last obtainable data, about 175 Water Works plants. Of these, one hundred and fifty five are small installations, as they supply a population of less than five thousand. In these small towns there is very little manufacturing, consequently the consumption is light, averaging surely not over five hundred thousand gallons daily, a total of say seventy five millions. Estimate that the ten larger plants in Iowa average a pumpage of five millions daily or fifty million gallons, and you will see that our proposition is correct, and that the above proportion will obtain in nearly every State; surely it will in the dominion.

Having established the fact that the aggregate pigmy is greater than the giant, we will assume another propo-

sition, the nature of which no one will deny; it is this, the average steam pump in use in most of these stations, we may say in universal use, is the most wasteful machine known to man. No one knows this and appreciates its enormity so well as the members of this Association, and it is largely to the man whose profits are going away with the rapidly diminishing coal pile that we present these suggestions.

It is safe to say that with the method of firing (which usually is as good as can be done under the existing conditions), the faulty boilers, and the pump just *devouring* steam, the average consumption of coal in the small stations throughout the country is not less than six pounds per horse power per hour. Those of you whose condition I describe, if you doubt it, at once make a careful test-run of your station for a week, just as it exists today, without any previous preparation, and if your engineer is doing as well as this, congratulate him, for very few are; if not, don't blame him, he is probably doing as well as he can with the outfit he has.

All this being conceded, as you surely will, our next thought is, to what shall we turn for practical relief from this condition, say practical, for you must not be unmindful of the fact that most water companies in small towns have to buy within their means—and their means, in many cases, are very small, as the coal agent has drawn all the dividends.

There does not appear to be any hope of relief through the steam pump or steam boiler. Go search the patent records, and in that wilderness of ideas you will not find one that has bettered the condition since the old high pressure machine was compounded generations ago.

True, we build a triple expansion engine of the horizontal type, and, with proper condensing apparatus, you obtain about one hundred million foot pounds duty, but it costs too much for our small man. The amount of water pumped don't justify the outlay, and there seems to be nothing that he can turn to in steam.

Leaving the steam pump entirely (and it does seem cruel and heartless to abandon so old and tried a friend) there appears to be very great hope of relief in the Gas Engine with Producer Gas, using either a centrifugal or plunger pump. Judging from some plants already in operation it would seem as if the question had been practically solved, and the town would be able to pump its little half million gallons, or even less, as cheaply per million as the city its one hundred million daily consumption, and all this with a plant of moderate first cost, and within their means.

The plant installed at Poughkeepsie, N. Y. will illustrate better than anything the writer knows, the character, cost and results of a small producer gas installation.

It was started in March 1905, so has been running now more than two years.

I take the liberty of quoting from the report of Chas. E. Fowler, Supt. of Public Works of that city, for 1905, giving the record of his plant from March to November.

"The centrifugal pump driven by a Gas Producer Gas Engine, for pumping into the filters, was erected in the winter and started March 22nd. The plant was accepted in June and since then the operation has been highly satisfactory."

The Gas Producer is a 50 H. P. Suction Producer and the Gas Engine a 35 H. P. two cylinder engine. The centrifugal pump is a 10 inch volute with enclosed propeller, driven by a 12 inch belt from the engine pully.

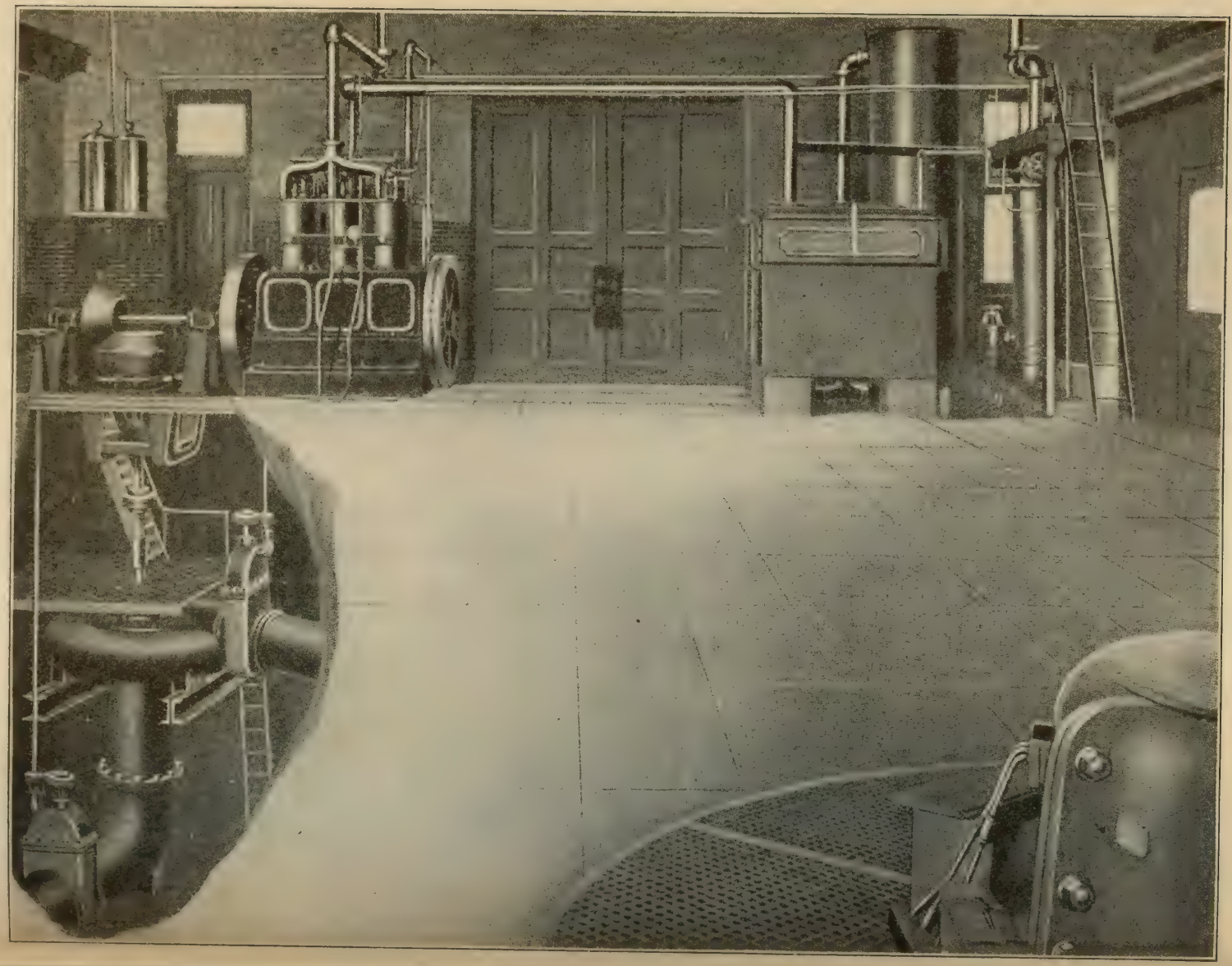
The plant is run continuously usually from Monday morning to Sunday morning each week.

The fuel used is anthracite pea coal of the quality usually used in pumping stations.

The following in brief is the result of a test made of this plant.

Duration of test 24 hours.

Total number of gallons pumped	3,200.362
Total lift of pump feet	38.73
Net horse power required	21.73



Combined efficiency of pump and belt determined from test of the engine	.56
Estimated efficiency of centrifugal pump	.61
Estimated loss by belt	.05
Power developed at shaft of engine H. P.	38.8
Total pounds of coal consumed	1,151.00
Pounds of coal consumed per hour	47.95
Pounds of coal consumed per H. P. per hour.	1.23

The duty of the entire plant is

$$\frac{3{,}200{,}362 \times 8.33 \times 38.53}{11.51} = 89.211{,}691 \text{ ft. lbs. per 100 lbs. of coal}$$

Mr. Fowler adds this note.

"In the three months, January, Ferbuary and March of this year (the three months preceding the installation of this plant) the steam plant pumping to filters used 223.59 tons of coal for 199.7 millions of gallons of water filtered, or, equal to 1.12 tons per million gallons. In the five months, July to November inclusive the gas plant used 78.16 tons for 317.8 millions gallons filtered. Equal to 0.24 ton per million gallons a saving of 0.88 tons per million gallons. As an average of 65.5 million gallons are filtered per month the difference in favor of the gas plant was 55.88 tons per month costing in the shed $3.26 per ton or $182.16 per month.

It will be interesting to know what this plant cost, and calculate how long at this rate it will take for the saving to pay for it.

The cost of the producer and gas engine was $3,000 erected.

The cost of the centrifugal pump was $440 erected.

Approximate cost of foundations, belting, water pipe connection etc. was $500. Total, $3,940, say $4,-000,

This saving pays for this plant in twenty two months, and, as it has been running steadily and successfully for over two years, it is all paid for now by the saving in coal.

In his report for 1906 Mr. Fowler says this plant has operated successfully during the year. The cost of repairs to the engine and producer has been $68.55, batteries and magnetos $31.40, total $99.95. The cost for oil for the engine $69.00.

The coal used per million gallons was 0.24 as against 1.12 tons used by the old plant.

The writer unfortunately has not been able to secure data from other gas driven pumping plants besides that at New Orleans, as those that he is acquainted with are running either on natural gas, or, as in the case of the Philadelphia Fire Service, on illuminating gas, their service being intermittent.

The New Orleans Sewerage is a producer gas driven plant with a centrifugal pump, arranged as shown by the accompanying sketch.

It consists of a three cylinder gas engine of 100 H. P. with suction producers.

In an official test of this plant, briefly, the result was as follows:

Coal per hour 77.2 lbs.

Coal per hour per H. P. 1.093 lbs.

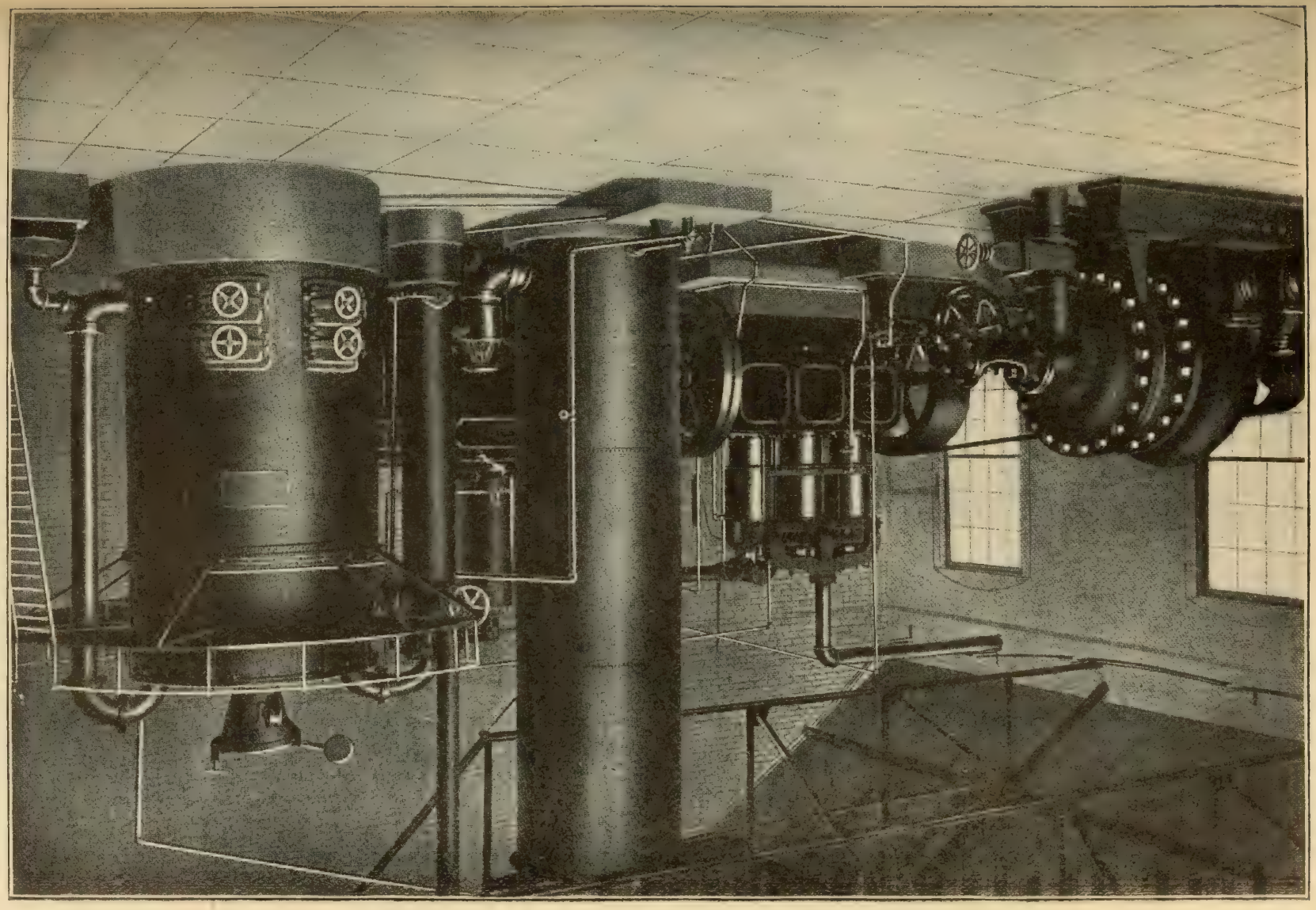
Duty 119.6 million ft. pounds per 100 lbs. coal.

Average head of water 13.05 feet.

This of course is a remarkable showing considering the low head, yet, as the test was made by their own engineers we cannot question the figures.

The next and most important question is, "Is the gas engine sufficiently reliable for a water supply?" The answer to this is, That no one set of machinery is sufficiently reliable for a pumping station, not even an old compound pump. If you have a duplicate plant to fall back upon you are perfectly safe, and why not a more economical one? Keeping your old pump for an emergency.

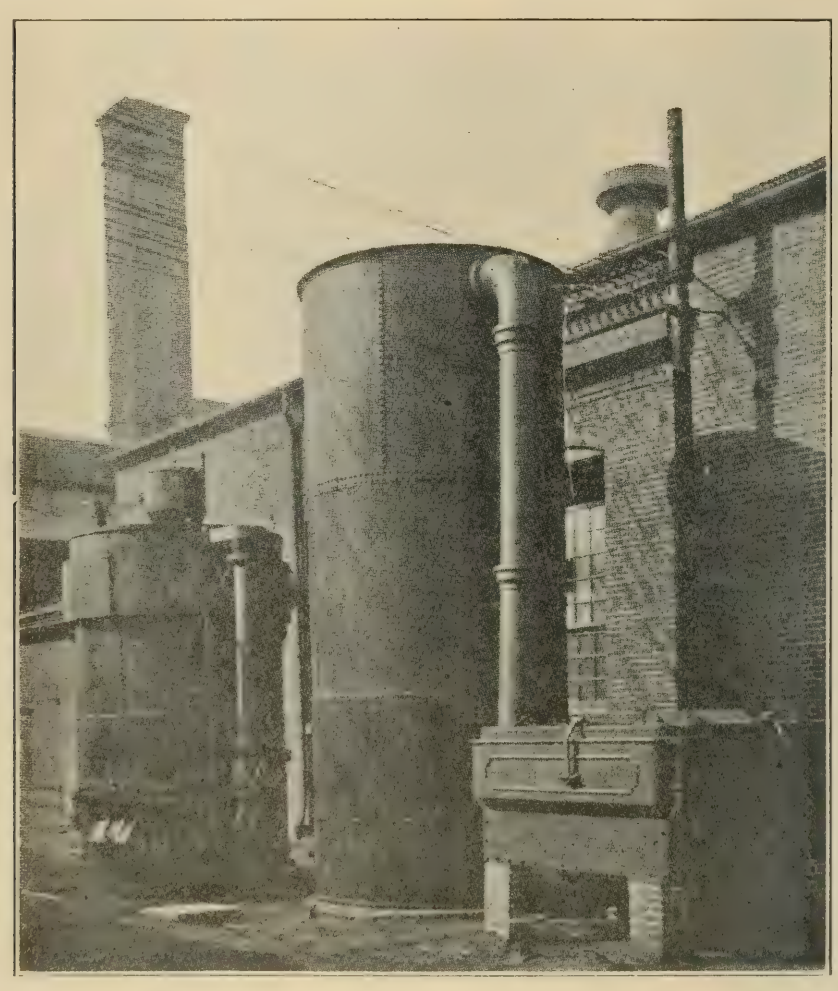
Mr. Fowler's experience quoted above shows that his repairs were about the same as would occur in a steam plant. He had one break down in 1906 due to a defective casting, but nothing serious, and his service during the year was almost constant, from this we



would infer that the breaks were no greater than would occur with a steam plant.

The use of the gas engine is so universal now that we may safely say that it is as reliable as a steam engine under similar service.

The writer saw one in England of four hundred horse power, running on producer gas, that had been stopped but once, and that for three hours, in over two years.



The installing of a producer gas plant would be largely in stations where your old steam plant would remain in reserve. In a new plant a sufficient factor of safety would be obtained by duplicating your engine plant, and having a spare producer. The producer feature of this installation being absolutely reliable. The spare produc-

er would only be necessry for cleaning, which is occasionally as essential to a producer as to a boiler.

A plant of this character is especially adaptable to an irregular service as the stand-by losses of a gas producer are very much less than a boiler and it can be started and in full operation much more readily, that is, in less time.

A suction gas producer such as would be used in the average small pumping station can be closed down for 48 hours with a stand-by loss of not over one seventh that of a steam plant, and may be started up to a working point in fifteen minutes. This, you will see is much better than it is possible to do with steam.

Another point, and a very important one in many communities is an entire absence of smoke or offensive smells, so a gas driven plant may be located where ever it is most convenient or desirable.

While a gas power plant may be of either the suction or pressure type, we have directed your attention especially to the suction form because we are speaking particularly of the small pumping installation.

The suction plant is a demonstrated success up to 300 H. P. in single producer units, although greater or less powers may be generated in a combination of two or more producers. It is the type which especially commends itself within the smaller powers because of its lower first cost, its simplicity of construction and operation, its less requirement in labor and space, while possessing a high thermal efficiency. Its essential difference from a pressure plant is that it requires no gas holder and the system of gas generation, cooling and cleaning is operated below atmospheric pressure, the entire apparatus being under several inches of suction.

Although differing in detail, design and arrangement all suction installations will consist of

A gas generator,
A water vaporizer,
A cooling and cleaning scrubber,
An expansion box, and sometimes—

A dry scrubber or purifier.

It will perhaps aid to a clearer conception of the simplicity and practical advantages cited above if we note more especially the detail of a given size. For this purpose I select a 75 H. P. plant with which I am familiar.

Such a plant will comprise a gas producer, an evaporator, a preheater, a wet scrubber, a dry cleaner or purifier and a hand blower for starting up the fire prior to the engine's operation.

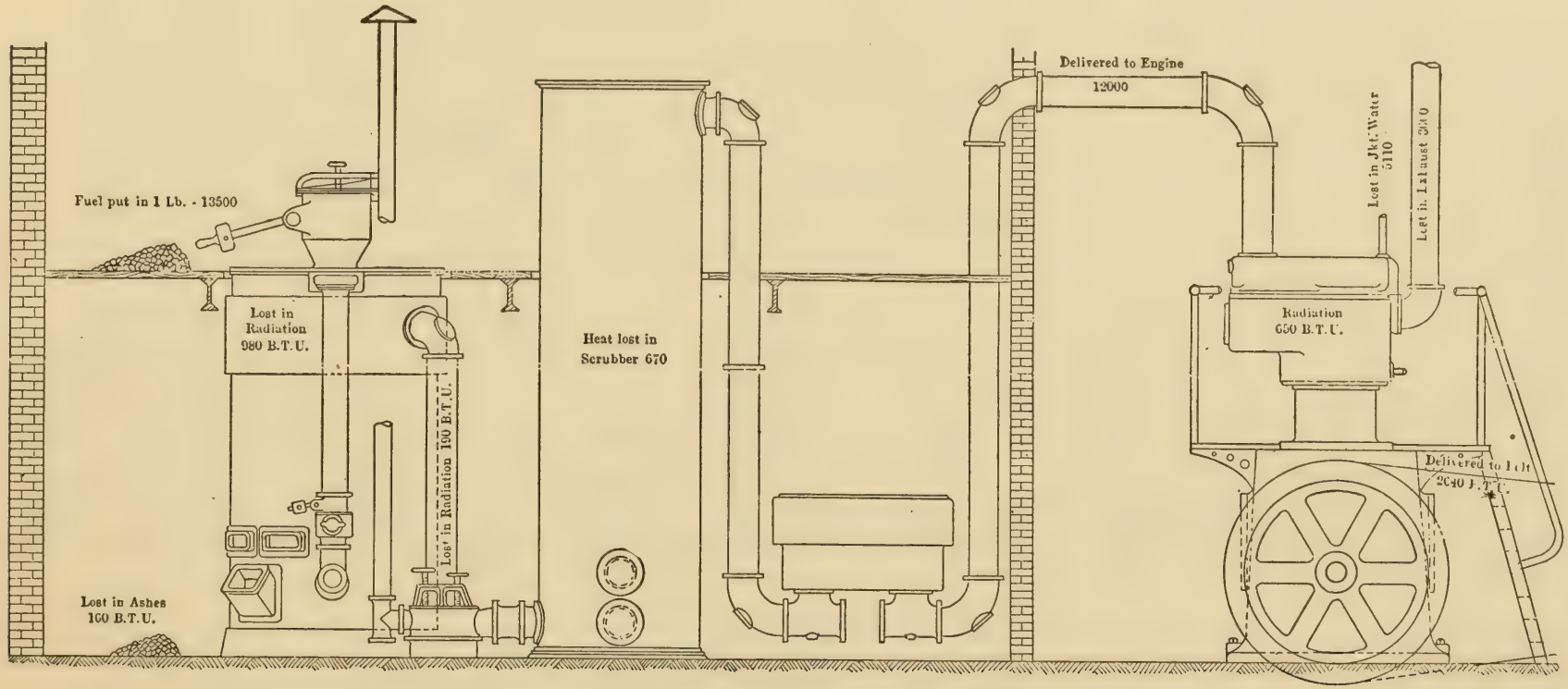
The producer is about 7 feet 6 inches high and 4 feet 4 inches in diameter, its lower portion (5 feet 2 inches high) being a steel shell, fire brick lined to an internal diameter of about 31 inches. The upper portion is a cast iron annular chamber containing water and serving as an evaporator, raising the steam required by the producer. The top plate is provided with a coal charging hopper, double-sealed so that coal may be charged into the producer without admitting air by suction. Poking holes are provided in the top plate and the grate may be stationary or revolved by a rack and pinion gear for the removal of ash.

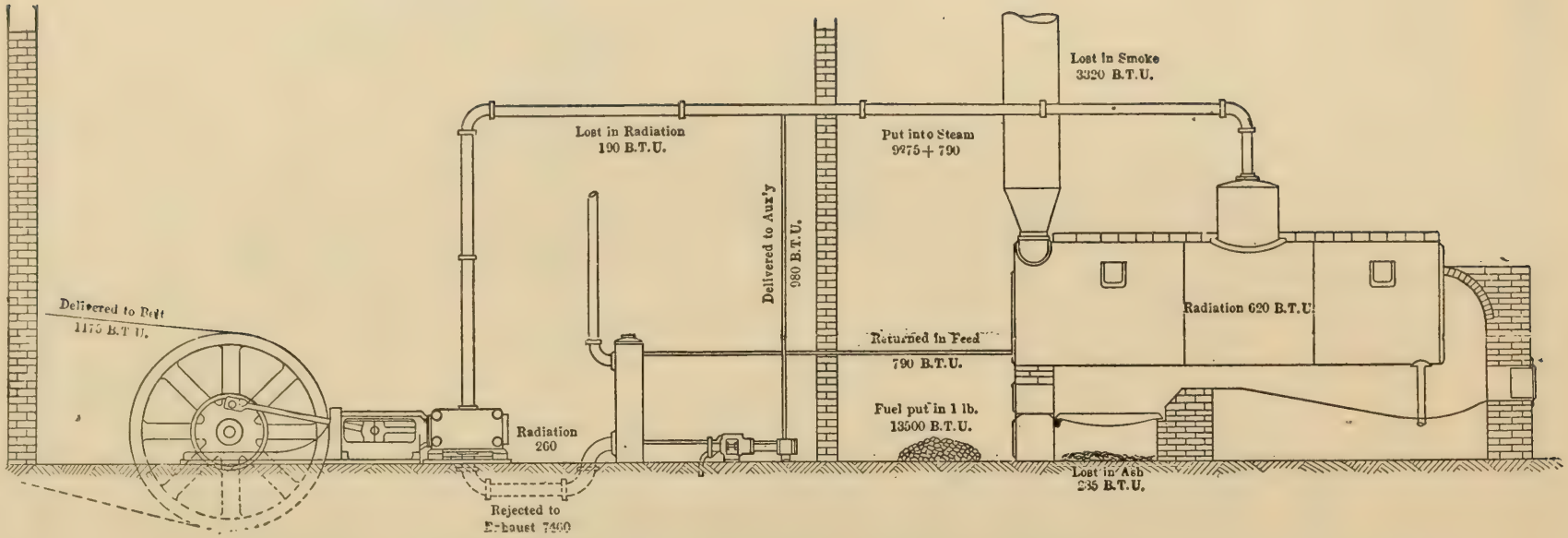
The preheater follows the producer, being essentially an 8 inch diameter pipe concentrically enclosed within a 14 inch pipe. The hot gas from the producer passes downward through the 8 inch pipe, while, impelled by suction, the air enters at the base of the larger pipe, circulates upward through the annular space, absorbing heat from the hot gases. The heated air passes by suitable connection through the evaporator and with the water vapor there taken up enters the base of the producer.

The wet scrubber, next in order, is simply a steel shell about 2 feet 9 inches in diameter and 12 feet high, filled with coke or other scrubbing surface suitably supported. A water spray at the top showers the coke constantly thus cooling and cleaning the gas rising through the coke and passing out at the top into the———————

DRY SCRUBBER, OR PURIFIER

This is of cast iron, about 4 feet 6 inches diameter by


Fuel put in 1 Lb. - 13500
Lost in Radiation 980 B.T.U.
Lost in Radiation 190 B.T.U.
Lost in Ashes 160 B.T.U.
Heat lost in Scrubber 670
Delivered to Engine 12000
Lost in Jkt. Water 3110
Radiation 650 B.T.U.


Lost in Smoke
3920 B.T.U.
Lost in Radiation
190 B.T.U.
Put into Steam
9975 + 790
Delivered to Aux'y
980 B.T.U.
Delivered to Belt
1175 B.T.U.
Radiation 620 B.T.U.
Returned in Feed
790 B.T.U.
Fuel put in 1 lb.
13500 B.T.U.
Radiation
260
Lost in Ash
235 B.T.U.
Rejected to
Exhaust 7460

3 feet deep, and provided with trays upon which is spread sawdust.

Of course ,suitable overflow pipes and connections are provided which we need not detail. The gas conduit to the engine is attached directly to the dry scrubber or purifier.

This 75 H. P. plant will occupy a space of about 12 feet by 22 feet allowing sufficient room for its operation. Its foundations are light and inexpensive.

To start and operate, a fire is built upon the grate and anthracite coal or coke added until the gas generator is full. During this period the air blast is supplied by the hand blower, the products of combustion passing through the waste pipe into the open air. As soon as good combustible gas appears at the test cock of the producer outlet, the waste pipe is closed and the gas turned into the gas cooling and cleaning apparatus. A test cock is provided on the engine connection and with the appearance of good gas there the hand blower is stopped and the engine started by compressed air from the air storage tanks. Thereafter the combustion is maintained by the indraft of air caused by each forward stroke of the engine piston. Once the gas is started, the only outlet for the gas is into the engine cylinder, hence the opening and closing of the gas valve on the engine controls the gas making which is therefore automatic, in proportion to the loads carried, and regulated by the engine governor.

Steam is used in the air supply to the producer to keep down the temperature of the fuel bed and avoid troublesome clinkering. As it is raised by the heat of the gases generated and which would otherwise be wasted in the cooling process, it gives increased economy. In passing through the fuel bed the steam is broken up into hydrogen and oxygen, its oxygen together with that of the air combines with the carbon of the fuel.

The net result of the operation is a combustible gas having an average heat value of about 135 B. T. U. per cubic foot, containing, say, 37% of combustible gas and the balance inert nitrogen and carbonic acid (CO_2),

15 per cent of hydrogen and 20—22 per cent of carbon monoxide with a little methane or marsh gas are the active agents. With such gas an engine using 12,000 B. T. U. per B. H. P. would require about 88 cu. ft. per horse power.

Such a gas installation will have a guaranteed efficiency of 75—80 per cent of the fuel value, and they have attained 90 per cent. One and one quarter pounds of coal per B. H. P. hour is a common guarantee at full load and better attained. A 300 H. P. suction plant which came under the writer's observation operated at 66% load, required on 1.37 lbs. of coal per B. H. P. hr. including the stand-by losses for 13 hrs. The average of a week's run on a load factor of 58, not including the nightly stand-by losses for 13 hrs. each night, was 1.33 lbs.

Unquestionably anthracite coal is the ideal fuel though suction plants operate well on thoroughly carbonized coke or charcoal. The use of bituminous coals in suction producers has not been satisfactorily solved, so far as the writer knows.

On pressure plants using soft coal or lignites a mechanical tar extractor is employed. It has the merit of a simple mechanical agency not likely to give trouble besides being an efficient cleaner. It resembles more nearly than anything else a Sturtevant blower, but is provided with a special arrangement of vanes and bafflers. Rotating at high velocity, the gas on entering is brought into contact with a water spray, or mist, and the combined intimate mixture and speed cleanse the gas of tarry matters and dust, adapting it perfectly to engine use. So perfectly is the gas cleaned by this process that a guarantee of purity is made to deliver producer gas from soft coal which shall contain not over .02 grains of tar and dust per cu. ft. It is curious to note that this is more free from foreign matter than the air we breath.

The cost, erected, of a 75 H. P. gas engine and suction plant would be under $5,000 and it would be guaranteed to give a B. H. P. on one and one quarter pounds of fuel, while that of the smaller plants is proportionate,

as illustrated by that of Poughkeepsie which has been already given.

It is not to be supposed that every manager of a water works is both a practical and theoretical engineer, and if they are that they have been afforded the opportunity of studying the theory of a gas engine. Many will therefore ask wherein lies this great economy in the gas engine over steam.

It is lamentable, when we consider that after a hundred years of scheming by the best minds the world has known, how small a percentage of the stored power in a ton of coal we have wrested from it, at the best not over one tenth of the liberated force, the rest passing off to waste. Over 90%, of all the coal mined for power purposes, in the world to-day, wasted. Some industrious statisticians has computed this to be ten thousand tons per hour.

Where does it go? up the chimney, radiation, waste, waste at every turn which we seem unable to arrest.

The gas engine somewhat betters this condition, and to show why it does, the writer has had prepared two sectional diagrams illustrating a steam and gas plant complete and wherein each sustains its loss. This has been compiled from a series of tests on both gas and steam plants so can be taken as approximately correct.

Had these calculations been made from the average steam pump instead of a reasonably good steam engine the comparison would be simply appalling.

So it would seem that there is some means of deliverance for the small man through a cheap and reliable plant, and the writer urges upon this Association that they shall not forget to keep alive this most important subject in their present and future deliberations.

DISCUSSION

MR. HAGUE: Mr. President: I think that a vote of thanks should be returned to the Captain for the very methodical, thorough, and intelligent manner in which he has cast forward the shadow of coming events. The gas engine with some sort of a pumping apparatus no doubt will occupy the attention of engineers and water works people in the near future; and for large capacities and under high pressures, study will probably have to be devoted to the water end question of the problem. In my own practice I have already gone into this line and among other plants, within ten days, have seen the award of contracts for two pumps driven by gasoline engines, which is, of course, the same thing as gas, for the gasoline is practically turned into gas before using in the engine cylinders. Figures for economic duty indicate that 200,000,000 foot pounds of work can be developed in the pumps for every 100 pounds of gasoline consumed. There is very little if any doubt, when we consider with what comparatively small capital a gas producing apparatus can be erected, how highly efficient the entire plant as a whole may be to own and operate.

No doubt the day will come, if the pump valves can be managed, that we shall have reciprocating pumps under high pressure—plunger pumps—running at high speed and operated by gas engines. A gas producer plant takes the place of the boiler; the coal is burned or distilled in the gas making part of the plant instead of being burned to make steam, and no doubt one of the secrets of economy in gas power, is that instead of producing steam from heat, 90 per cent of which heat is latent heat and which we cannot recover after the water is evaporated into steam, (the steam plant being handicapped in this direction) in producing gas the heat is placed in such a position as to be very much more available. The line of mechanical competition will likely be about as follows:

In the steam machine, where heat is wasted to a very great extent on account of the latent heat involved in making steam,—that is heat which does not show on the thermometer we are accustomed to seeing, in this steam ma-

chine, the mechanical efficiency and economy is very high, which means that a very large percentage indeed of the power developed by the engine goes into useful work. But in the use of the gas engine, on account of high speed of rotation desirable for various reasons in the gas engine, the work of pumping water is accompanied by certain losses of a purely mechanical nature; and so the high heat economy is somewhat discounted by a lower actual power efficiency appearing in the net work done. In brief, the steam machine has a comparatively low heat economy but a very high mechanical economy; while the gas machine has a very high heat economy and seemingly can only be applied under bad mechanical conditions regarding the pumping of water. In small and moderate sized plants it will not pay to put the capital into high class steam pumping engines for the reason that the actual cash economy per year does not amount to enough to justify the investment, that is, it will will pay to burn more coal which comes out of the current earnings instead of making the permanent investment of capital too high in the plant. But, with the gas plant it looks as though an investment no more than a wasteful steam plant calls for, can be put into an outfit which will return a much higher current coal economy. How high in capacity this line may be profitably followed in substituting gas for steam, is not yet known, but it will be thrashed out in due time just the same as some other matters have been. Anthracite coal is ideal material for making gas, but the use of soft coal brings the by-product tar into the account, and the keeping of this out of the gas engines means the expenditure of a part of the power developed and constitutes a charge against the plant. But we shall see. Everything will take its proper place in the steady march of time. Try all things, hold fast to that which is good.

PREST. MAURY: I should like to ask Captain Tarr about what his figures are for the estimated cost of a producer plant with centrifugal or turbine pump, about what the cost per horse power would be, say, in a 50 to 200 H. P. plant erected.

MR. TARR: I have given here as an example, a 75 H. P. plant, costs $5,000. My idea is to keep the expense down for the small man. I want to find some relief for the Water Works of moderate capacity that are compelled to spend all their money for coal and make no dividend. Five thousand dollars should give him this relief in most cases and he should have his plant paid for, as Mr. Fowler has done in Poughkeepsie, in two or three years.

I desire further to say that after a great deal of discussion of this matter with many engineers and particularly with my associate, Mr. John Lewis, it is yet undetermined under what heads and conditions a gas plant can compete with a steam plant. You may get to a point where the increased cost of the gas plant is hardly paid for by the economy in coal. This was illustrated recently in Atlanta. There specifications were open to every type of engine for an engine of 15,000,000 gallon capacity. When we first read the specifications we thought there was a chance for a gas plant, but when we came to make our estimates for both steam and gas, we found that we could not compete with the gas engine against steam guaranteeing 150,000,000 gallons duty under the conditions of service. In presenting this paper I do not want to take the broad general ground that a gas engine plant will take the place of a steam engine in every case, but I do say that so far as the old steam devouring *pump* is concerned it is time to put it on the back shelf and begin to get some profit out of the small water works plant.

PUMPING WATER BY PRODUCER GAS PLANT AT ST. STEPHEN, N. B.

F. A. Barbour.

The town of St. Stephen is situated on the St. Croix River, which at this point forms the boundary line of the Province of New Brunswick, Canada, and the State of Maine. On the opposite side of the river is the City of Calais and upstream a short distance, are the towns of Milltown, Me., and Milltown, N. B. For twenty years these communities have been supplied with water taken from the river by the Maine Water Company. Increasing pollution of the stream by a growing population and particularly the development of a large pulp and paper plant at Sprague's Falls had given rise to more or less dissatisfaction with the water and on the expiration of the twenty year contract the Town of St. Stephen determined to establish municipal works.

Many surface supplies were investigated by surveys and analyses of the water in an attempt to obtain a gravity system; but in all cases the water was found to be so impregnated with vegetable coloring matter as to be unfit for use. Attention was then turned to ground water supplies and a point on the Dennis River, a small stream entering the St. Croix below St. Stephen, was chosen for investigation by wells and pumping tests—the location selected being a gravelly intervale in the valley of the stream.

The first wells failed to yield but a limited amount, but finally, near the lower limit of the flat land where the surrounding hills draw close together, water was found in large quantities. A test of several weeks duration in the driest period of a dry year developed a supply of more than two million gallons per twenty-four hours from a test well six by eight feet in horizontal dimensions and thirteen feet deep. The quality of the water was ideal, hardness averaging 2.4 parts and iron .0022 parts per 100,000.

The elevation of the normal water level in the ground at this point of supply is one hundred and fifty feet above

the principal streets in the Town, thus greatly reducing the necessary pump lift. The Canadian Pacific Railroad track runs within a few hundred feet, permitting economical construction of side track and adding to the attraction of the location. It was accordingly determined to construct an open well, twenty feet deep and thirty feet in diameter, and to erect a pumping station at this point, lifting the water into a concrete reservoir situated on a hill some fifteen hundred feet to one side of the main pipe line to Town.

Up to the time the work was ready for receiving tenders the water company looked upon the municipal investigation as merely a piece of strategy to obtain better rates in a further contract but when fully convinced that an economical supply had been found and realizing that their present source must be abandoned, negotiations were begun by the company to obtain from St. Stephen the water required to supply the adjoining towns on the river. Since such an arrangement greatly reduced the cost of water per gallon this proposition was accepted by the authorities of St. Stephen, and it was finally agreed to furnish water at Twenty-four Dollars ($24.00) per million gallons by Venturi meter measurement. The total daily quantity thus made necessary will run from one million two hundred thousand gallons to one million six hundred thousand gallons. Incidentally it may be stated that with an actual pump lift of one hundred and thirty -five feet into the reservoir a pressure of eighty pounds at the hydrants when drawing ten standard fire streams, will be maintained in the principal streets of the town.

The pumping plant in such a system as that under discussion is the determining element in the cost of water. The time has gone by when an engineer can afford to accept steam as the source of power without consideration of other means. Gasoline or oil engines, electric motors, where current can be cheaply obtained, and gas producer plants, all demand consideration with a justification, in each case, depending on local conditions. In Canada, and in fact anywhere, with the present price of gasoline, this source of energy is out of the question except in small works where the standby losses and cost of attendance would, with other methods, be large in proportion to the amount of actual work

done. Heavy oil engines at the present price of this fuel have much to commend them for small installations but cannot usually compete in final economy with plants of other types. In the present case, steam, gas producers and electric power merited consideration. Electricity to compete in the pumping of water, especially where the transmission line is relatively long and a relay engine of some type is necessary for emergency use, must be obtained at less than three-quarters of a cent per kilowatt hour. This could not be done at St. Stephen and the choice, therefore, narrowed to steam and gas producer plants. In relative reliability the writer believes there is very little difference between these types of plants; in point of attendance there would be but little difference in the ordinary water works station although there is probably less work to be done in the case of a producer plant. The actual labor in handling the fuel is much less in such plants and the attendant has more time for other work.

While, however, the operation of producer plants is simple, it is more difficult at the present time to obtain attendants who appreciate the requirements and are in sympathy with this type of apparatus than in the case of steam plants. An engineer who has long been running steam engines if put in charge of a producer plant is apt to be prejudiced.

Believing that the choice at St. Stephen rested on the relative economy in first cost and cost of fuel, bids were asked on both steam and gas plants—the propositions to be based on two complete units, each of one million, eight hundred thousand gallons capacity in twenty-four hours and the bidder to name a guaranteed duty.

In order that the bids might express the actual relative value to the Town, as far as possible, it was required that the duty should be based on the total coal used in a three days' test, engines to run eight hours and fires to be banked sixteen hours—all coal used in banking and all standby losses to be charged against the plant. Such a test is absolutely necessary in producer work as no reliable results can be obtained in short runs and in steam plants, where boilers are included, the average ten hour test is often very misleading. In the latter case if the run is started and stopped without

drawing the fires the difference in amount of combustible on grates at start and stop, as manipulated by a clever fireman, will frequently involve an error of from five to six per cent. in the duty obtained. In producer work it is much more difficult to estimate the relative amount of combustible in the producer at any one time and the period of the test run must therefore be extended long enough to eliminate, so far as possible, the personal equation and reduce the percentage of error. In power plants of different types the relative fuel consumption during hours of banking is most important. In the average high duty steam pumping plant running eight to ten hours and banking the remainder of the day, as observed by the writer, the coal used in banking will run from twenty to thirty per cent. of the total coal used or from four-tenths to six-tenths of a pound per nominal boiler horse-power hour of banking. Such plants in actual operation usually develop a duty in hours of running equal to from eighty to ninety per cent. of that developed in a ten to twelve hour duty test and, including banking, usually develop a station duty from sixty to seventy per cent. of the test duty. The short run test does not always develop the relative commercial or station economy of steam installations and in a comparison of steam and producer plants the standby losses must be taken into consideration. It is claimed that gas generators can be banked with less than one-tenth pound of coal per horse-power hour of banking. With these facts in mind, as stated above, the St. Stephen guarantee was based on a three day run under conditions as nearly approaching those to be met in actual operation as possible.

The contract in regard to the test reads as follows:

"The duty test shall start at nine A. M. in the morning, with the fires in condition as found after banking the preceding night, and shall continue for three (3) days, the test being completed at nine (9) A. M. of the morning of the third day, and the plant being charged with all the coal fired in the producer during the intervening time. The pumps shall operate each day from nine (9) A. M. until five (5) P. M., and the fires will then be banked for the night. Salvage from ash to be fired without weighing.

The pumps shall operate, as nearly as possible, at the rate of twelve hundred and fifty (1,250) U. S. gallons per minute, with a total head of one hundred and seventy-five (175) feet.

A preliminary test will be made to determine the slip of the pumps; measurements of water pumped being ascertained in this preliminary run by pumping into the reservoir, which will be used as a meter.

In the duty test of power pump, the work done shall be estimated from the reading of the revolution counter, and the displacement of the plunger, allowance being made for the slip, as determined in the preliminary run.

The total head will be determined by the reading of the pressure gauge on the force main, plus the reading of the vacuum gauge on the suction pipe, plus the distance between the centres of these gauges.

The test shall determine the duty per one hundred (100) pounds of fuel (of quality equal to that specified by the contractor) developed by the pump when operating at the rate and under the conditions above specified; the plant to be charged, as specified above, with all fuel entering the producer during the three (3) days' run of the test, including that required for banking, but excepting that coal which is sifted from ash can be refired without weighing."

Proposals were received on two steam plants and three gas producer plants. The first costs of the steam plants varied from sixty to eighty per cent. of that of the gas plants, but the duties guaranteed were more than correspondingly reduced. On the basis of using pea anthracite in producer and Nova Scotia bituminous coal for steam work, both at $5.00 per ton, there was no doubt but that the producer plants were much the cheaper proposition.

Some of the gas propositions were based on the use of centrifugal pumps, connected to the engine by silent chains, but the reduced efficiency, as estimated by the bidder, more than made up for the lesser cost of this type of pump as compared with triplex power pumps. Apparently an efficiency of sixty per cent. was estimated in the case of centrifugal pumps and seventy per cent. with triplex pumps.

The proposition accepted: this included two Pintsch system suction gas producers, with necessary accessories, two 4-

cycle single cylinder heavy duty engines, and two double acting, triplex power pumps, each of twelve hundred and fifty gallons capacity per minute. The Contractors guarranteed a duty of one hundred and fifteen million foot pounds per one hundred pounds of pea anthracite coal having a thermal value of thirteen thousand B. T. U.'s per pound, with not to exceed ten per cent. ash nor eight per cent. volatile matters, not two per cent. sulphur.

The generators, whch have each a rated capacity of one hundred and twenty-five horse-power, are constructed of boiler iron, twelve feet, nine inches high and four feet, three inches outside diameter, lined with fire brick and the space between fire brick and shell filled with mineral wool. The fuel is fed through a double closing shotpouch hopper. This hopper is mounted on a cast-iron plate which is pivoted on a verticle pin and can slide on another cast-iron plate which is bolted to the outer lid of the producer. The lower plate has an aperture which leads to a conical fuel magazine in the upper part of the generator. This sliding lid, with ground joint surfaces, serves to permit of charging the generator with fuel without allowing the escape of gas or inrush of air.

The grates are of the so called shaking basket type, especially adapted for the pea anthracite coal which this producer is to use. Large cast-iron doors with ground joint surfaces are placed above and below the grate on the two opposite sides of the producer, rendering the fire place and ash pit readily accessible. A cast-iron pipe extends vertically from the ash pit into a concrete sump in the floor below the generator which is kept filled with water and thus provides a water seal. In this way the ashes can be discharged through the ash door or through the water seal.

The gas after leaving the generator passes through the vaporizer which is a cast-iron shell containing a number of vertical tubes, the space around the tubes holding water and the gas passing through the tubes on their way to the scrubber. The steam formed in the vaporizer is led through piping provided with the necessary valves to a steam jet, where it is mixed with air and led under the grate through the water seal pipe. This latter arrangement insures the air

being admitted at the centre of the grate, resulting in an even distribution through the overlying mass of fuel.

The steam jet works under a pressure of less than one and one-half pounds per square inch and is designed to secure a constant and uniform mixture of air and steam in excess of the requirements under any varying load conditions, the excess steam being carried away through a galvanized iron pipe to the outside of the building.

The lower part of the vaporizer is formed by a casting having openings leading to the scrubber and one to the relief pipe, which serves as a chimney during the hours when the engines are not taking gas from the generator. A cast-iron wall divides this lower portion of the vaporizer along a vertical line, extending from the top of this section of the vaporizer toward the bottom in such a way as to form, by the admission of water, a seal which, when the engine is stopped and the relief pipe open, prevents gas from the vaporizer entering the scrubber. The manipulation of this water seal is effected by valves provided in the piping.

The scrubbers are made of boiler iron twelve feet eight inches high and three feet, two inches outside diameter and contain a removable grate for the support of the coke. The gas enters the bottom and leaves at the top, coming in contact in its passage through the scrubber, with water which is admitted to a sprinkler system attached to the scrubber cover. After passing the scrubber the gas is led by a vertical pipe to a cleaning pot which serves to collect large particles of moisture which may have been carried over by the gas and thence to the cleaner, which is a circular boiler iron shell, five feet, six inches in diameter and thirty-two inches high, fitted with two wooden trays, supporting layers of sawdust through which, by baffles, the gas is forced to pass vertically downward. The provision of this ample capacity in scrubber and cleaner is believed to be a valuable insurance against the passing over to the engines of dust and tar products, which lead to the minor difficulties in operation sometimes attributed to the use of this type of plant.

Each producer is equipped with a gauge board with water gauges showing the vacuum in the different parts of

the apparatus. The piping is so arranged that either engine can be operated from either producer.

For blowing hot the producer when starting an air jet is provided, the air being taken from the compressor used for starting the engine.

The engines are 4-cycle, horizontal single cylinder, with one fly-wheel and outer bearing, with shaft extended to receive friction clutch by which the engines are connected to the pumps. The engines are nominally of one hundred and fifteen horse-power and are designed to operate at one hundred and fifty revolutions per minute.

Regulation is accomplished by the so called quantitative principle, by which the quantity and not the quality of the admitted explosive mixture is changed to accommodate the varying loads. This is obtained by a variable lift inlet valve, directly controlled by a centrifugal governor, mounted on a vertical spindle and driven by means of spiral gears from the lay shaft of the engine. The governor is guaranteed to regulate within three per cent. of rated load and hand-controlled attachment permits a fifty per cent. reduction of speed under control of the governor.

The lay-shaft is of polished open-hearth steel, running in phosphor bronze bearings, carrying at the crank end hardened spiral gears which effect a reduction in movement of lay-shaft to one-half that of the crank-shaft. The other end of the lay shaft carries the main cam, which operates the inlet and exhaust valves and the ignition apparatus. An auxiliary cam, also fastened to this shaft ,serves to actuate a valve in the cylinder head which can be used alternately as the compressed air starting valve or as the relief or blow-off valve—the change being effected by throwing a lever in between two bosses.

The inlet valve gear consists of a lever pivoted on the shaft of the cylinder head bracket and carrying in two bronzed bushed bearings the pin, which supports the roller which rests on the main cam. Another two bushed bearing on the same lever receives the pin which is fastened to the push-rod operating the inlet valve lever. This latter lever is a steel forging, forked at the end where it hooks into the inlet valve crosshead. The variable lift of the

inlet valve is attained through the governor by changing the point of fulcrum of the inlet valve lever—the shifting of the fulcrum block nearer to or further from the inlet valve reducing or increasing the travel of this valve.

The exhaust valve is operated by a cast-iron lever pivoted on a pin having two bearings in the cylinder head bracket and carrying, at one end, a roller through which it comes in contact with the main cam of the lay-shaft. Its other end is forked and faced with hardened tool steel blocks, on which rest two rollers, which in turn are pivoted on two pins of the exhaust valve crosshead.

The exhaust valve is a solid crucible steel forging, turned out hollow to receive cooling water, which is admitted through slots in the valve stem guide and shank of the valve itself. Provision is made for altering the tension of the valve spring and for adjustment to compensate for any wear of the valve seat. The cooling water is applied to the different parts of the engine from a common cast-iron header and individual pipes, controlled by valves, makes possible the regulation of the amount of water going to each part of the engine, water being supplied independently to the cylinder head, exhaust valve case, cylinder jacket and exhaust pipe jacket. Thermometers on the outflow pipes make possible the maintenance of an even temperature at different parts of the engine.

The ignition device consists of an oscillating low tension Bosch magneto, operated by a lever, pivoted on an eccentric pin and receiving its motion from the main cam. By shifting the position of this eccentric pin the time of tilting the magneto is altered and so the time of ignition. The igniter is of the make and break type, consisting of a stationary insulated pole, wired to the magneto and of a movable hammer part which is abruptly separated from the stationary pole at the end of the magneto oscillation, when its movable sleeve regains normal position under the action of two springs. The transmission of movement from magneto lever to igniter hammer is accomplished by means of an arm forming part of this lever and operating with it. To deaden the noise when striking igniter hammer this arm is provided with a rawhide face.

The bed frame of engine is of the heavy duty, self-contained, center crank type, with cylinder water-jacket cast in one piece. The cylinder head is flanged to the frame and clamps the inserted cylinder liner in place. This cylinder liner is a cylindrical tube of cast-iron with a flanged-like projection at one end which fits in recesses turned in the bed frame and in the cylinder head. The piston is of cast-iron, ribbed and fitted with seven cast-iron compression rings. The piston pin is of solid forged crucible steel, and the connecting rod is a solid, open-hearth forging, provided with adjustable bearings at each end; that at the piston end being of phosphor bronze and that at the crank end of steel lined with babbitt. The main bearings are of similar construction having steel shells lined with babbitt and provided with two oil rings. The crank-shaft is an open hearth steel forging, with throw cut out of solid block. The crank is counter-balanced by two cast-iron weights.

Special pains have been taken in the lubrication of the engine, an oil pump supplying the cylinder through a sight feed and oil cups serving to lubricate the lay-shaft bearings and the piston pin.

Mention has already been made of the combination, starting, blow-off and relief valve. The valve proper consists of a casing containing three poppet valves, dividing the casing into three chambers. When starting, the levers that operate these three valves are brought into contact with an auxiliary cam by means of a special hand lever. The engine having been barred into position and the hand lever thrown to the starting point, compressed air is admitted into the cylinder, resulting in the piston, crank-shaft, lay-shaft and auxiliary cam moving, until by the action of this cam, the compressed air valve closes. On the return stroke of the piston the valve leading into the cylinder opens and also the valve into the vent pipe, thus allowing the compressed air to escape. This operation is repeated automatically until the engine starts to fire. The operation of blowing off while the engine is running, to remove impurities and excessive oil from the cylinder, is accomplished by throwing the hand lever in an opposite direction from that necessary for start-

ing; the result being that the valve between cylinder and vent pipe is open during a certain part of the explosion stroke.

Gas and air admitted to the cylinder head valve chamber through a cast-iron pipe, divided by partition into two conduits, one for the gas and the other for the air, with provision for controlling the amount of gas and air in order to obtain the desired mixture. The air is taken through piping from above the roof of the building.

The exhaust gases are carried through one length of water cooled pipe and then through a non-jacketed cast-iron pipe to a combined muffler and heater below the floor of the engine room, from which they are carried to an exhaust funnel above the roof. The muffler and heater is a double walled cast-iron cylinder, with a section of tubes inserted between two headers, the gases passing through the pipes which are surrounded by water. By this muffler it is proposed to provide the necessary hot water for heating the building.

The engines, as above stated, are of one hundred and fifteen horse-power nominal capacity. This is larger than necessary for the economical operation of the pumps the size being determined by the intention of the authorities to employ these engines in the future development of electric current for the lighting of the Town.

The fly-wheels are twelve feet in diameter with fourteen inch belt face and weigh twenty-six thousand pounds. A self-contained hand barring device is provided in each fly-wheel pit.

The engines are connected with the pumps by means of a heavy duty friction clutch.

The pumps are of the ordinary triplex, four stand, double acting type. These pumps are geared to run thirty-two revolutions per minute. Rawhide pinions keyed to the shaft extending from the clutch, transmit the motion of the engine to the gears of pumps. The pump cylinder is thirteen inches in diameter and the stroke twelve inches. The two pumps have a common suction pipe, eighteen inches in diameter, leading from the well with individual suction pipes fourteen inches in diameter. The discharge pipes are twelve inches in diameter and connect with the fourteen inch force

main leading to the reservoir. Check valves are provided in the discharge of each pump and also straightway valves in the discharge and suction pipes thus permitting the entire isolation of either unit. Relief valves, with outlets piped into the suction, are also provided.

The auxiliary apparatus in the station includes an air compressor, driven by a pelton wheel, with the water taken from the pressure main and returned to the well. The compressed air is piped to two receivers erected on the producer platform, each thirty-two inches in diameter and six feet high. Compressed air is also employed in two stationary air-lifts, provided to raise or lower the exhaust valve of the engines. These lifts are attached to the engine foundations and facilitate any repairs or inspection of the exhaust valve or its mechanism.

The station building is of red brick and includes the engine room, generator room and coal-shed. Above the engine room and connected with it by an iron spiral stairway is the office and bath-room. The generator room has a concrete platform, eleven feet above the floor, and at the same elevation as the floor of coal-shed, thus permitting all coal to be transferred from the point of storage to the producers without lifting. A railroad siding permits the coal to be shovelled directly from the cars through the roof of the coal-shed. Care has been taken in the producer room to use concrete or brick throughout, both in walls and floors. Windows are provided in the wall between producer room and engine room so that the operation of the engine may be observed by the attendant, either when on the ground floor or the charging platform.

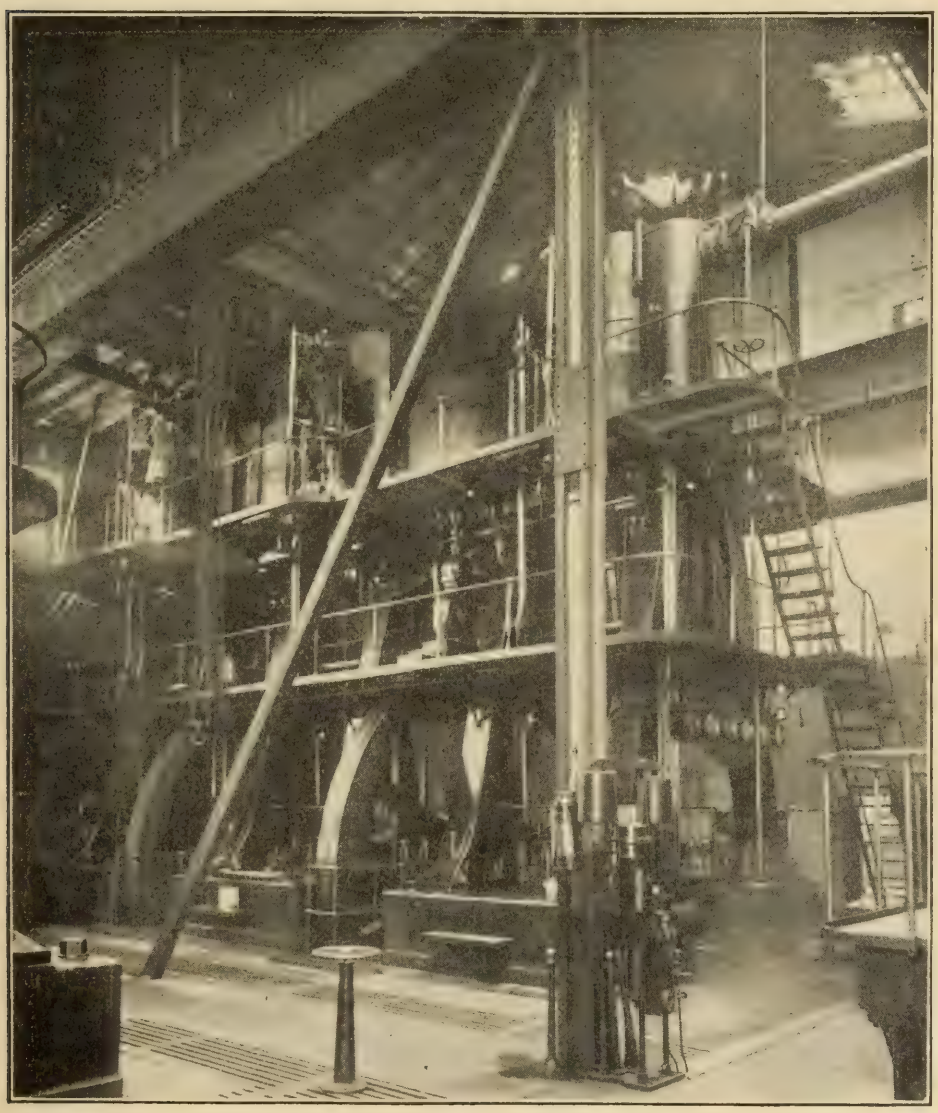
Note:—The test of the plant, owing to unavoidable delays, not being made in time to include results in this paper, they will be given in a separate paper at the next convention. (The Author)

ELECTRICALLY DRIVEN CENTRIFUGAL PUMP, BUFFALO, N. Y.

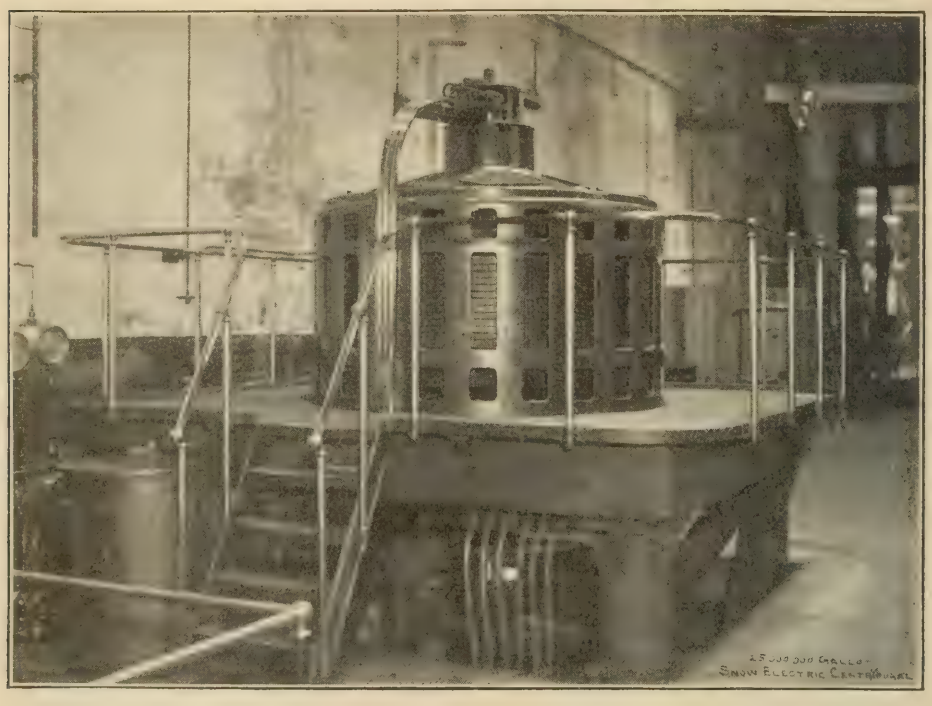
Henry L. Lyon.

A contrast in pumping machinery is shown in the attached pictures of two pumps standing side by side in our pumping station at Buffalo; one a triple expansion steam pump; the other an electrically driven centrifugal pump.

The triple expansion steam pump is 20 by 40 ft. in plan, and 40 ft. in height. It has a capacity of 30,-

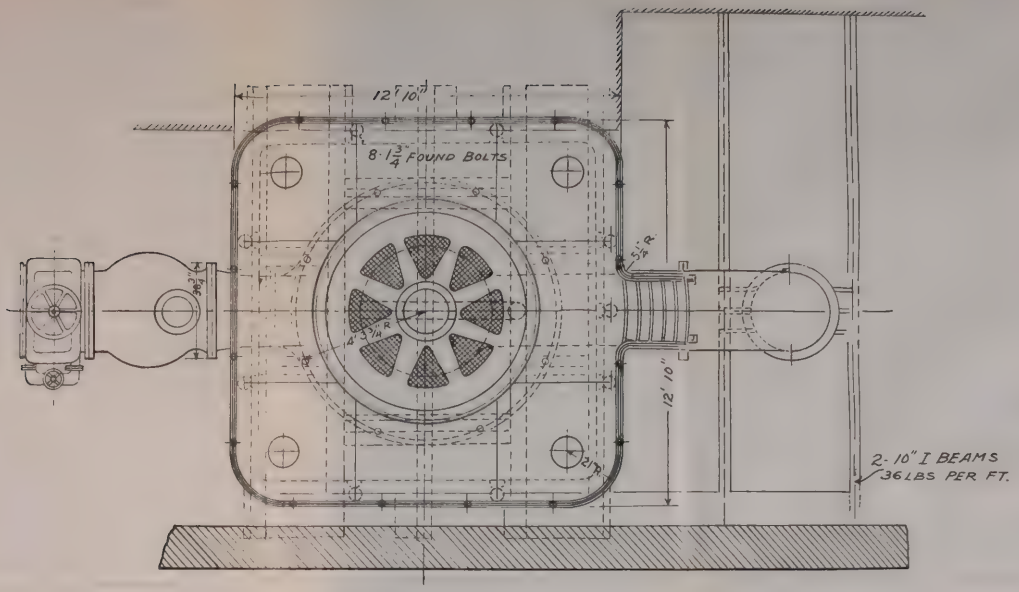


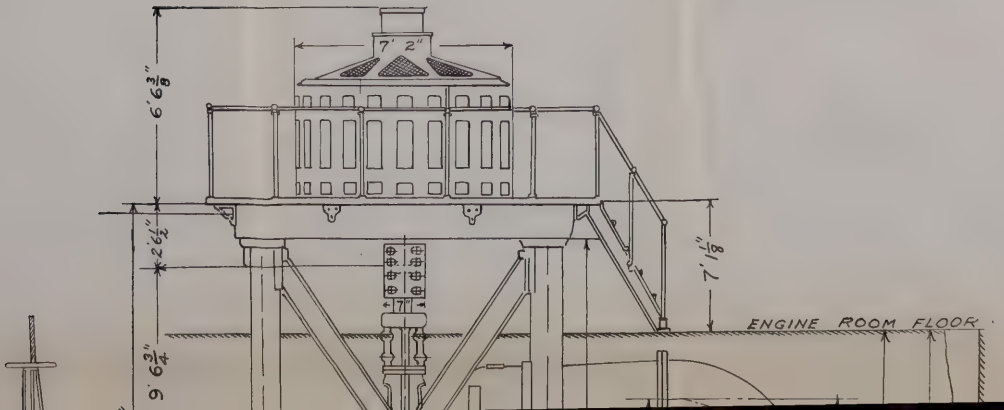
000,000 gallons in 24 hours; pumping 1079 gallons with each revolution. There are 1,188 valves in the pump chambers; each fly-wheel weighs 32 tons. The engine is 1,200 horse power. The cost including boilers and connections, $140,000.00.

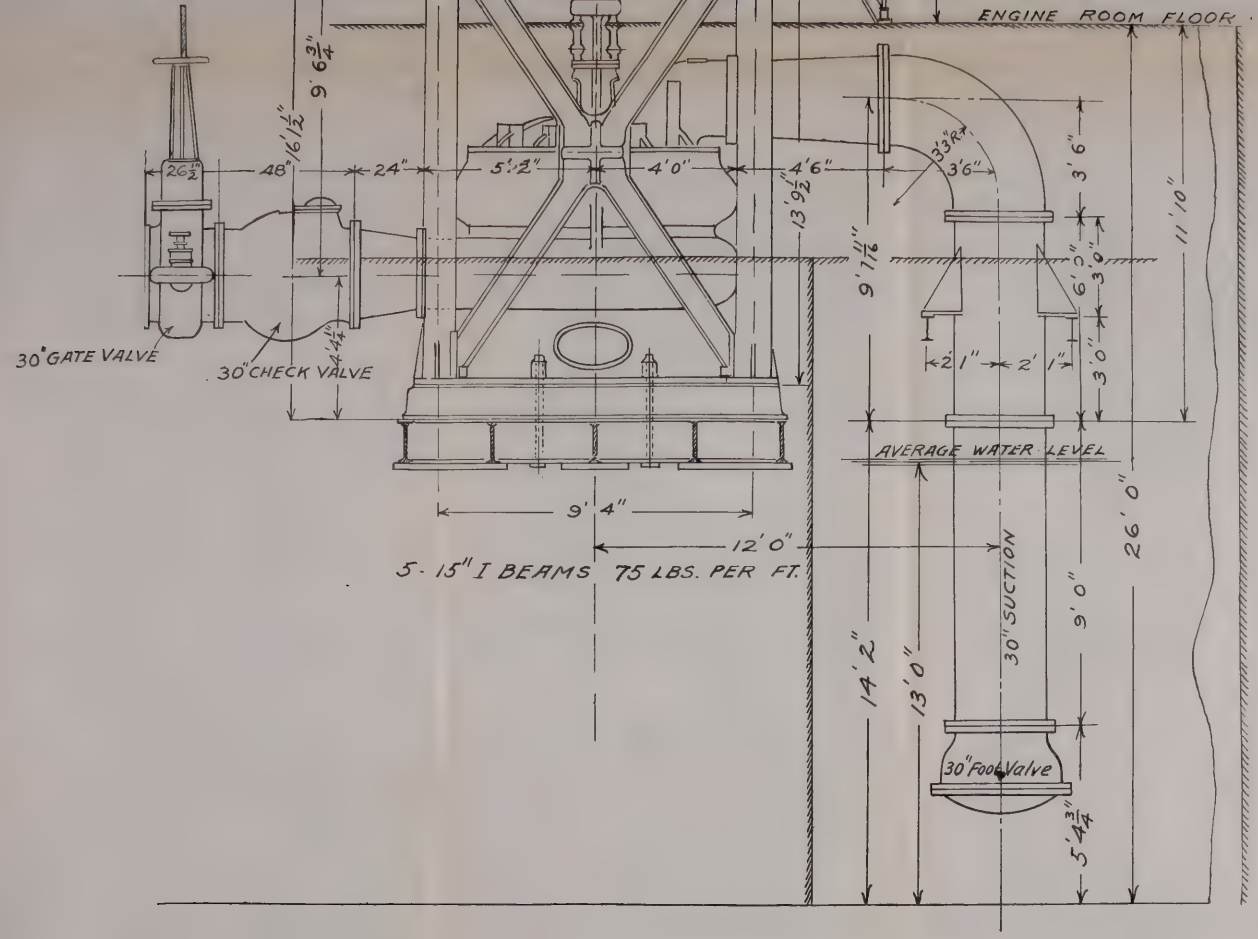


The electrically driven centrifugal pump is 13 by 13 ft. in plan, and 24 ft in height. It has a capacity of 25,000,000 gallons in 24 hours against 200 ft. head. There are no valves in the pump chamber, and no fly-wheels. The motor is 1,500 horse power. The cost, including pump, motor, transformers and connections, is $30,490.00.

The steam pump you are all familiar with in a general way, and needs no explanation here. The electric pump is a two-stage, vertical shaft, turbine type, with an annular casing containing an impeller 52 inches in diameter, and a set of fixed diffusion rings and vanes. The water enters the top of the casing at the center, and is thrown out through the diffusion vanes into the discharge chamber. The vanes corresponding in function to those of the turbine wheel. A vertical shaft extends up from the pump to the motor, situated


12' 10"
8-1¾ FOUND BOLTS
12' 10"
2-10" I BEAMS
36 LBS PER FT.


7' 2"
6' 6⅜"
2' 2½"
9' 6¾"
7' 1⅛"
ENGINE ROOM FLOOR



GENERAL ARRANGEMENT
OF
24"-2 STAGE VERTICAL TURBINE PUMP

SCALE $\frac{3}{8}$" = 1 FOOT

NOVEMBER 18th 1904

HENRY R. WORTHINGTON
NEW YORK.

directly over the pump. The motor is a 1,500 horse power, general electric, squirrel cage, induction motor. The motor and pump run 500 revolutions per minute. The suction and discharge pipes are 30 inches in diameter. The electric current is furnished by the Cataract Power and Conduit Company, coming from Niagara Falls, at 11,000 volts, and stepped down to 550 volts by transformers in our station.

During the year ending June 30th, 1906, we pumped 20,115,216,144 gallons of water with steam power on the low service, 50 lbs. to the square inch; and 20,078-765,766 gallons with steam power on the high service, 75 lbs. to the square inch; and from Aug. 20, 1905, to July 1, 1906, 7,810,386,930 gallons with the Electric pump on the high service. The electric pump having been completed and put in operation Aug. 20, 1905. This would make the total pumpage by the electric pump for the year ending June 30th, 1906, if it had been in operation for the year, 9,107,959,200 gallons. It actually pumped more than 25,000,000 gallons most of the time and was shut down ten times (a day at a time) for cleaning.

A comparison of the cost of the steam and electricity is probably best made by taking the items directly necessary to the two methods of applying power on the high service, eliminating all general management and overseeing of the pumping station, which would be necessary in either case, and in our station also takes care of the low service.

The pumping of 20,078,765,766 gallons on the high service by steam required:

28,604 Tons of Coal at $2.15 per Ton	$61,498.60
6 Engineers, at $3.25 per day	7,117.50
8 Oilers, at $1.75 per day	5,110.00
6 Wipers, at $1.75 per day	3,832.50
3 Foremen of Firemen, at $3.00 per day	3,285.00
9 Firemen, at $2.50 per day	5,475.00
9 Coal Passers, at $2.00 per day	4,927.50
2 Boiler Cleaners, at $45 per month	1,080.00
Total Cost of Service	$92,326.10

Value of 3 Steam Pumps, with Boilers, etc., $140,000, $420,000. Interest one year at 3 per cent	12,600.00
Total	$104,926.10

Water Pumped.	Cost with Int.
20,078,765,766	$104,926.10
Cost per million gallons	$5.22

The pumping of 9,107,959,200 gallons on the high pressure by electric power required:

1,500 Horse Power at $25.00 per Horse Power per year, Contract for Year,	$37,500.00
3 Electrical Engineers, at $3.25 per day	3,558.75
3 Oilers, at $2.00 per day	2,190.00
Total Cost of Service	$43,248.75
Cost of 1 Electric Pump and Motor, with Transformers, etc., $30,490.00 Interest one year at 3 per cent	914.70
Total	$44,163.45

Water Pumped.	Cost with Int.
9,107,959,200	$44,163.45
Cost per Million Gallons	$4.84

You will see I have not taken repairs into consideration in the above figures, but they cut a large figure in economy in favor of the electric pump. No repairs have been necessary on the electric pump, and there is little to repair. The impeller blades might break, or, in a long use, become worn. The motor is so large that it never will be overloaded, and hence, extensive repairs are remote.

The steam pumps, of course, are almost always needing repairs, especially the valves in the water chambers.

The life of the electric pump is something upon which we can only speculate, but I can see no reason why it should not be as long, and probably longer, than the steam pump.

We have a 30-inch Venturi Meter on the discharge pipe of the electric pump, and for the last month there has been something the matter with the quantity of the discharge, it having dropped off about 3,000,000 gallons per day. At this time of year our pumpage is so increased, on account of the cold weather, that we do not like to shut down a pump for repairs, if it can possibly be avoided, so we have not taken it apart to ascertain the cause. This will be done, however, before the convention meets, and probably in time to amend this part of this symposium.

MR. LYON: Since the time referred to in the paper we have examined the pump, and the only trouble I found was that the impellers and the vane on the outer circuit are badly pitted, as I supposed from the action of the water. We frequently have sand in our water. The impellers are made of solid bronze and the vanes are lined with bronze. They seem to be so badly cut up that the upper impellers will have to be replaced entirely. Whether there is some material that would be better than bronze for this purpose is what we are now trying to decide. If anybody can decide it for me, I would like to know it.

DISCUSSION.

MR. SANDO: We are all interested in the relative cost of pumping water by steam and electricity. It seems to me that it might be construed, from the statements made, that these costs can be taken in a general way, instead of referring only to the conditions obtaining in Buffalo. In the first place, the capacity of this centrifugal pump was assumed. To quote from the paper, it says "If it had been in operation for the year" the amount pumped would have been so much and that the 30-inch Venturi meter was out of order so that the capacity of the pump was based simply on the manufacturer's rating and now Mr. Lyon says that the pump has worn some. Of course under these circumstances the comparison cannot be taken as reliable at all.

There are two points that are very strongly brought out in this paper; first, the low cost of electricity, which is probably due to the favorable location of Buffalo with respect to the source of power. The other is the extremely high cost of pumping by steam which is, I think, due to the inefficient machinery. The record of costs of pumping and other data of different pumping plants in the United States, which was compiled from information sent to the Commission on Additional Water Supply in New York by representative engineers of these plants, shows that for the year 1902 there were seven municipalities pumping their entire water supply cheaper than Buffalo, and the cost was less for fifteen individual pumping stations in different municipalities, so that this comparative cost between pumping by electricity and by steam cannot be taken as a representative of the real ratio of difference.

We are all familiar with the very high records of economy in pumping made in Boston; but machinery in Boston is no better than in a number of other cities. It is taken care of nicely, but it can be taken care of and the same economy obtained in a dozen of other stations of the United States the same as in Boston; but taking the Boston figures, which I happen to have here for the years 1900 to 1904 inclusive, and taking as a basis the year 1904, when the Metropolitan Water Board paid $3.87 a ton for their coal, as against $2.50 a ton in Buffalo, with one engine in

operation which pumped about one-half of the capacity of the steam plant in Buffalo, and the head pumped against was 130 feet instead of 172 feet; but reducing these to the same basis, except in Boston the cost of repairs to the plant are included, it makes the cost of pumping water in Boston about $4.00 per 1,000,000 gallons put into the reservoir as against $5.22 at Buffalo. That is putting every thing on an equal basis of comparison, and I think gives a very good idea of the actual cost of pumping in the two places. As I said before, I think that there are a dozen pumping stations in as many cities of the United States where they are pumping water at a good deal less cost than in Buffalo, and a great deal less cost than the price quoted or given for electrical pumping; that is, notwithstanding the very low cost of electric current there. Now these remarks are not intended at all to be detrimental to the progress of pumping water by the centrifugal pump. The centrifugal pump is here to stay; it has its place, but we all recognize that very often it gets out of it.

MR. HAGUE: Mr. President and gentlemen of the Association. There is an old saying with which we are all familiar, to "prove all things and hold fast that which is good," and the innovation of the turbine pumping machine comes under that injunction. The reciprocating engine has a long record, and the rates now being obtained are no doubt about the limit of possibilities of a practical steam pressure under average water pressures; and the pressure shown here against which this machinery is working in both cases is pretty nearly the average waterworks pressure, 200 ft. head. The author starts off by making a comparison of the space required, cost, etc.; but it seems to me that the value of an article and the usefulness obtained from it, is the real basis. It may pay you in some cases to pay three times the price, if your fixed charges and running expenses and repairs will justify it; and of course that is the true basis. In making his comparisons he says this is in the interest account. Now there are a great many other charges against pumping stations besides interest account, and the paper develops one of these, which is depreciation. This centrifugal pump has fallen off more than

ten per cent of its capacity for no other reason than pitting or wearing of the runners. Of course, that is a direct charge against the depreciation of the machine; and in making his comparisons for his footing page he gets the price per million gallons. I think Mr. Lyon has no doubt been handicapped by the absence of opportunity to separate some of these items in practice. It is very difficult in each pumping station to eliminate certain things so that you can find out the exact operation. He must have included more than one engine in his reciprocating machine, because he refers in one place to 8 oilers. Now 8 oilers must cover a great many other items. He speaks of three foremen of firemen. There are not many stations that require three superintendents of the fire-room outside of the men that handle the coal. It seems to me that it would be a much fairer comparison if one of the units at Buffalo were taken, say the 30-million unit by itself, to run that engine continuously, and to make the comparison on that basis. There are engines at Buffalo of various efficiencies, some of which are pretty low. When you group three or four engines together and take out one of the best, it does not seem to me hardly a fair method of comparison. Another thing, the mere difference of 38 cents per million gallons does not tell the story; you must pump enough gallons per annum so that the difference would cover the fixed charges. If you ouly compare say 10 million gallons a day at a difference of 38 cents, it would not go very far toward paying for anything in the course of the year. A mere difference of 38 cents in favor of the centrifugal machine means nothing at all in the absence of other very important details. I have recently computed a table of engines running from low duty direct acting engines to the highest size of triple expansion machine, and giving the cost of the interest on the machinery, depreciation, small repairs, wages, maintenance and everything that goes to make up the cost, and the expense of the owning and pumping runs from about $13.50 per million on a small compound condensing engine down to $4.92 on the large vertical triple expansion engine against a water-head of about 200 feet, and with coal at $3.00 a ton. The mere

difference in cost per million gallons does not tell the whole story, for the reason that the quantity of water pumped must be sufficient so that the difference in the cost per million gallons will amount to money enough to justify the purchase of the higher cost machine. Of course we know the records for pumping water in Boston have very often gone below $4.92 per million gallons, and I think it would be very much to the point and very satisfactory all around if Mr. Lyon would give us a later paper on this subject with the conditions so prescribed that we could see at a glance that we have both machines on a common ground. Of course, there is no doubt whatever about the turbine engine having come to stay. There is plenty of field for it; but I think it is a long way short of proving its case when pumping water for municipal supplies against the average water works head.

The one excuse for attempting to live, upon the part of the centrifugal pump, so far at least as concerns waterworks pumping, is low first cost of plant; and it goes without saying that the machine, for any certain purpose, of the lowest first cost with all other balances at least equal, will prevail; but this brings us to a realization of the further fact that the present prominence of the centrifugal pump is simply due to a reversal of the arguments of 25 years ago, when the high duty steam pumping engine with its higher first cost forced its way to the front by the showing of the capitalized value of its reduced coal account, as compared with the cost of fuel necessary to maintain the power of the low duty pumping engine. The main difference between the increased interest, maintenance, and sinking fund of the high duty engine of a quarter of a century ago and the decreased items of the centrifugal machine of to-day, is that the high duty reciprocating pumping engine rapidly and conclusively proved its case, while the present centrifugal pump has so far failed in so doing, and to all appearances never will be able to acquire and maintain the leading position as an apparatus for pumping water with acceptable economy under every day pressures and conditions of municipal supply.

The speaker has had to do with, and has tested, centri-

fugal pumps in water-works plants, but from observations so made can see no hope of such machinery successfully competing, in anything but first cost of plant, with the reciprocating type of apparatus, under ordinary water-works conditions. The fallacious advantage of apparent low initial cost really places the centrifugal pump back in the low duty class of several years ago, from which the water-works plants have just about worked clear, after a long and expensive experience. The present issue seems to be commercialism against engineering, with the buyer's interest secondary. The friends and exploiters of the centrifugal pumping plants talk glibly about 80% test efficiencies, and of 75% every day efficiencies, but in the hands of disinterested people, intent only upon learning the facts, the 80% shrinks down to about 65%, and the ordinary efficiency sinks to a little over 50% of the power applied.

Under low heads, and with comparatively small quantities of water, where the revolutions per minute of the centrifugal pump come down within reach of direct-connected steam or gas engines, the working economy is satisfactory; but with the high rate of revolution under which the centrifugal must be worked to meet say 200 ft. head of water or more, either a belted machine, a steam turbine, or an electric motor, must be employed, and such applications of power have not so far been able to compete in economy of operation with the reciprocating steam pumping engine. Such examples may be found in service at a cost of $9,000 per annum for a pumpage of 4,000,000 gallons per day by centrifugal pumps operated by electricity, as against $16,000 per annum for coal for 14,000,000 gallons of water delivered per day by steam pumping engines. This means that with both plants reduced to a 4,000,000-gal. basis, the reciprocating machinery would earn 5% per annum on the sum of $87,600; and with both plants on a 14,000,000-gal. basis, the reciprocating steam plant would earn 5% per annum on $310,680. This may look like an extreme comparison, but the gross records of water pumped and money paid for electric current and for fuel are plain enough. A 4,000,000-gal horizontal cross

compound steam pumping engine, giving a steam duty of 100,000,000-ft.-lbs. per 1,000 lbs. of steam (and this ought to me easy enough these days) will pump 4,000,000 gals. of water per day against 100 lbs. water pressure, with an expenditure for fuel per annum of $5,201, with coal at $3 per net ton, and an actual evaporation of 8 to 1 in the boilers. The difference between this result and $9,000 per annum for the same amount of water pumped by electrically driven centrifugal pumps will pay 5% on $75,980, and the cost of a steam pumping plant, including buildings, chimney and everything excepting the land, at $10,000 per 1,000,000 gallons capacity, which would be high, amounts to only $40,000 for a 4,000,000-gal. plant.

The discrepancies in the above comparison are very great against the centrifugal pump, but aside from the inherent comparative disability it is becoming manifest that impellers wear rapidly in centrifugal pumps, when under high velocity and considerable head.

The paper which brought out this discussion referred to records of a falling off of 12% in the delivery of water due to the wearing of the impeller, as compared to the calculated or calibrated capacity of the machine when new. The speaker knows of a case wherein two 12,000,000-gal. electrically driven, single-stage centrifugal pumps were installed to work against 257 ft. head, the contractor having the utmost confidence of success before the pumps were put into place. The pumps absolutely failed to deliver satisfactorily against the head, and then two-stage pumps were substituted. The latter were more successful, but after several months' operation it required both pumps to deliver the required quantity of water, although one of the pumps was supposed to have a margin of one-third its capacity above the regular demands; and the water pressure maintained averaged only about 80% of that required by the contract. These two-stage pumps, which followed the single-stage pump, are now being replaced by other centrifugals, of a different design and make.

Another case is recalled wherein a pumpage of 10,000,000 gallons per day against 110 lbs. load was required, and which could be easily accomplished with reciprocat-

ing steam machinery by an expenditure of $10,000 per annum for coal, but where an attempt to drive centrifugal pumps by electricity would result in a cost for electrical power, at $6.50 per 1,000,000 gallons of $23,725 per annum; showing a difference in favor of steam that would pay 5% per annum on $275,940. There is no conceivable difference in cost of machinery, buildings, maintenance, attendance, or anything else that would justify such a preference for electricity and centrifugal pumps over steam and reciprocating pumps. There is no mystery about the matter, as may be seen by the following facts:

10,000,000 gals. against 110 lbs. pressure =	440 pump HP.
120,000,000 steam duty, with 8 lbs. evaporation in the boilers, and with coal at $2.50 per net ton delivered.	$9,928 per annum.
Electric power at $6.50 per 1,000,000 gals. means 3,650 million gallons per annum at $6.50, amounting to	$23,725 per annum.
The difference in cost for the elements of power is $13,797, which at 5% would capitalize at	$275,940

The electrically driven, centrifugal plant was tried, commencing about three years ago, and it is safe to say that everyone is disappointed in the results, and it is whispered that although the contract was executed in the autumn of 1903 no money has yet been paid to the contractor.

Coming directly to a comparison between electrically driven centrifugal pumps and reciprocating steam driven pumping engines in the Buffalo water-works, as set forth in the paper before the convention, it seems to the speaker that a much more equitable comparison, and one more in line with the interests of the buyer, would be as follows:

COST OF OWNING AND PUMPING WITH THE HIGHEST TYPE AND CLASS OF STEAM MACHINERY.

One unit of 25,000,000 gals. against 87 lbs., (200 ft. head.)

Pump horse-power	870 HP
Vertical triple expansion pumping engine, 450 boiler HP. of boilers	
Engine house and foundations, and engine foundations	$150,000
Boiler house and foundations, and boiler foundations	
Coal storage building	

Pumping engine:

Interest	4%
Sinking fund	5%
Depreciation	2%
Oil, waste, etc.	1%
Total	12%

Boilers:

Interest	4%
Sinking fund	5%
Depreciation	5%
Total	14%

3 Engineers; 6 Firemen; 3 Oilers;
Coal, $2.10 per net ton.

Summary for steam, reciprocating machinery:

Coal per annum	$11,957.40
Wages per annum	9,900.00
Capital charges on engine	13,920.00
Capital charges on boilers	1,260.00
Capital charges on buildings	1,548.00
Total charges per annum	$38,585.40

Cost per 1,000,000 gals., $4.11.
Cost per horse-power, $43.16.

COST OF OWNING AND PUMPING WITH THE HIGHEST TYPE OF ELECTRO-TURBINE PUMPING MACHINERY.

One unit of 25,000,000 gals. against 87 lbs. (200 ft. head.)
Pump horse power ..... 870 HP.

Two-stage, electrically driven turbine pump..	
Engine house and foundations, and pump foundations	
Transformer house and foundations.....	$43,750
Auxiliary house and foundations	
Transformers, lightning arresters, conductors, controllers, and all auxiliary apparatus..	

Pumping machinery, motors, etc.:

Interest	4%
Sinking fund	5%
Oil, waste, etc.	1%
Depreciation	2%
Total	12%

3 Engineers; 3 Extra men; Electric power at Buffalo, $4.50 per 1,000,000 gals.

Summary for electro-turbine pumping machinery.

Electric current per annum	$41,062.50
Wages per annum	5,700.00
Capital charges on machinery	4,314.00
Capital charges on buildings	468.00
Total charges per annum	$51,544.50

Cost per 1,000,000 gals. $5.64.
Cost per horse-power, $59.24.

The steam plant saves enough to pay 8.6% on entire cost of steam plant. Electric power must be sold at Buffalo at $3 per 1,000,000 gals. to balance the steam plant account, and the depreciation charge of 2% is very probably too low for the electro-turbine apparatus, according to experience so far; while 2% is perfectly safe for the steam plant depreciation so far as the engine is concerned, and the sinking fund of 5% is likely 2% too

high for the steam plant , while 5% is very likely too low for the electro-turbine machinery for sinking fund. All of the certainties are in favor of the steam and all of the chances are against the electricity.

MR. BURDICK: Upon last Monday the speaker had the pleasure of visiting Buffalo and examining the centrifugal pump that Mr. Lyon has described. Fortunately the pump was taken apart at the time of the visit, and I was able to examine its interior.

It is a two-stage machine of the Worthington turbine type. The impellers are of the enclosed type, and are constructed of bronze. Diffusion veins receive the water upon discharge from the impellers. The body of the diffusion vein is of cast iron, but the tip for a distance of probably 10 inches is constructed of the same material as the impeller.

I was informed by Mr. Cloudley, engineer of the station, that the water delivery of the pump remained constant for about one year, after which it was observed to gradually fall away. The pump was recently taken apart to ascertain the cause of its reduced efficiency, disclosing the fact that the upper runner and the diffusion veins are badly pitted. Mr. Cloudley attributes the pitting to the action of sand, which at times of storm is carried in considerable amount in the water of Lake Erie, from which the Buffalo supply is taken. The marks are of such a peculiar character, and so unevenly distributed, that it seems strange that they could have arisen from the cause named. As before stated, one impeller only and one set of diffusion veins were affected; about one-third only of the impeller blades were marked. These marks occur in patches about as large as one's hand. The marks were from one-eighth to one-fourth of an inch in depth, and in one or two instances where the mark occurred near the tip of a blade, the blade had apparently worn thin and broken off. The marks were not lined, grooved or polished, as one might expect from the action of sand, but were quite rough, and had the same general appearance as metal that has been eaten away through electrolysis or galvanic action. A portion of the bronze tips of the diffusion veins were pit-

ted in the same manner as the impellers, and it was observed that the pitting was much the deeper upon the cast iron bases of these veins, the pitting in the cast iron reaching a depth of nearly one-half inch in spots.

The speaker has frequently observed the action of sand in reciprocating pumps and other machines, and has never noted a case due to the action of sand where the markings were similar to that upon the Buffalo pump. Aside from the appearance of the markings it seems significant that the scars should occur upon one runner and upon one set of diffusion veins only, as evidently what passed through one impeller must have passed through both, and would be expected to leave the same mark upon each.

PREST. MAURY: I would like to ask Mr. Lyon whether any action that might either be attributed to sand or to electrolysis has been noticed upon the parts of any of his other pumps; whether he has had a chance to see his valve cages and plunger barrels in his vertical triples?

MR. LYON: Nothing that we have ever noticed of that kind.

MR. FRENCH: Not having received the advance copy of the papers before leaving home, I am not prepared to give any precise figures with relation to cost of pumping per million gallons, but wish to state that the Hackensack Water Company is operating two stations, in one of which there are three verticle triple expansion engines,one 12, one 18, and another 20 million gallon capacity, and where I know the cost of operation per million gallons is considerably less than $4.00.

At the second station the cost somewhat exceeds $4.00, due to the fact that the conditions of operation are such that we cannot run the engines at the percentage of their capacity, that we should, in order to obtain the most economical results.

MR. HEWITT: I would suggest that the pitting at Buffalo may be due to electrolysis. If there were groves caused by the sand, they would appear in the direction taken by the sand and water; on the other hand, pitting by electrolysis would take place in just the way that they described it.

HIGH DUTY VS. LOW DUTY PUMPING ENGINES.

Irving H. Reynolds.

Twenty-five years ago when the high duty pumping engine was a high-priced machine of very special design and consequent high cost, the controversy between the high and low duty pumps was a very spirited one, but with the standardization of types and consequent reduction in cost, the high duty engine has taken its place as the accepted machine for general water works' service, while on the other hand, the low duty engine has been vastly improved in economy, so that it has in no sense been displaced, but has gained a field quite its own, though as the limit of usage of either type of machine is not sharply defined, each occasionally overlaps the other's field.

For pumps of large capacity, say above 5,000.000 gallons, there are comparatively few cases where the low duty machine can be considered, but for capacities up to 3,000,000 or 5,000,000 or occasionally somewhat above, a choice must frequently be made between the two types.

As the conditions surrounding the operation of pumping machinery vary widely, it is not possible to lay down any hard and fast rule for determining the most advantageous type; it being necessary to consider each case by itself, but it is the purpose of this paper to call attention to certain of the more important points involved in reaching such a decision.

While the figures given in some of the following tables are applicable to any type of machinery of a given economy, yet for the purpose of confining the discussion to commonly accepted types, consideration of centrifugal pumps however driven, air lift pumps and direct-acting pumps with high duty attachments will be eliminated, and the discussion confined to reciprocating plunger pumps.

Some of the reasons for omitting these types are: First, that the centrifugal pump is a special machine which, while well adapted to certain classes of work, especially for pumping large quantities of water under very low heads, or for emergency work, or for locations distant from the source of motive power, yet as it is a machine giving its best results only when operated at a constant capacity against a constant head, its efficiency falls off rapidly on any departure from the normal in either particular, and it cannot be considered, at this time, as having established a permanent position for general water works' service.

The air lift pump is a very special machine, and as a rule is used where no other type of pump is feasible—therefore, the question of economy is sacrificed to practical convenience in operation.

As to the direct acting pump with high duty attachments, in which class come the Worthington, D'Auria and Heisler types, experience has shown that these attempts to substitute "something just as good" for a fly wheel have not been either mechanically or commercially successful, and the direct-acting triple expansion duplex pump, or the simpler form of compound fly wheel pump has practically taken the place which they sought to occupy.

Of course all types are not equally suitable for every location, and whether the engine is to be horizontal or vertical, compound or triple expansion must necessarily be determined by local conditions.

Horizontal engines naturally cost much less than vertical, and in the small sizes under consideration are perhaps equally satisfactory.

Generally speaking the following holds true:

All large engines should be of the "vertical" type; vertical engines should have single acting plungers; vertical fly wheel engines should preferably be of the "triple expansion" type; all direct-acting engines should be of the "horizontal" type; all pump plungers should be outside packed excepting for very light pressures with clean water.

In guaranteeing duties, engine-builders commonly use 1000 pounds of dry steam as the basis, and it is quite proper to do so for several reasons, because it gives a practically uniform standard for comparison, it eliminates the question of variation in quality of fuel, skill of firemen, and other factors over which the engine contractor, as a rule has no control, and therefore puts the pumping engine proper on its own merits, yet as the purchaser is primarily interested in the cost of operation, fuel must necessarily enter into his calculations.

In arriving at a choice, two main points are to be considered, i. e. first cost and cost of operation.

Under the first item, are properly included the cost of the engine foundations, boilers, buildings, etc., and under the second item, fuel, supplies, attendance, depreciation and repairs.

In arriving at the first cost, it may be safely assumed that the cost of foundations, buildings, etc., would be substantially the same for either type of engine, but the capacity of boilers required is proportional to the duty, and therefore the increased cost of boilers is properly chargeable to the lower duty machines, so that the item of first cost should include both the engine and boilers.

Under the cost of operation, the most important is that of fuel, and in engines of the comparatively small size under consideration, this may be taken as the only point of difference between the two types.

While doubtless arguments will be made over the relative cost of attendance, supplies, depreciation and repairs, yet experience has failed to show any measurable difference, excepting in the larger sizes of vertical high duty machines where the cost of maintenance has reached a remarkably low figure, and under all circumstances these items for the high duty engine may be safely assumed as at least as low as for the low duty machinery, although for the purpose of simplifying the calculations, it has been assumed above that in all types of engines, the depreciation and repair account is a certain percentage of the first cost, yet this is not

strictly true, particularly when high speeds are entered into; the depreciation and repair account being almost in direct proportion to the number of strokes per minute of the engine.

Mere piston speed has very little to do with the wear of machinery, but the number of reversals in a given time determines the wear; this bearing particularly on the life of pump valves and wear of journals and pins, so that an engine of short stroke and high revolutions will have a much higher depreciation account than one of longer stroke and slower revolutions, although perhaps operated at a higher piston speed.

The question of the lower duty shown under every day working conditions as compared with that of official tests, is a matter which, for the purpose of this paper, must be considered as practically the same for any type of engine, although as a matter of fact, the writer believes that the falling off in duty of direct-acting pumps is greater than that of the fly wheel machines, due principally to the failure of the direct-acting engines to make their full strokes unless the cushion valves are frequently and carefully adjusted.

The causes for the lower duty under every day conditions are many, the most common of which is carelessness on the part of the engineers in failing to operate machinery under the conditions for which it was designed. As regards the coal duty, it is practically impossible to keep the efficiency of the firemen up to anything nearly approaching that prevailing during a test.

As far as the loss in economy in the engine itself goes, the most common cause of this is the operating of the machinery against pressures very much lower than those required for the duty test, and no greater mistake can be made than to purchase machinery stipulating that the duty test shall be made against, say, 100 pounds water pressure, when the actual pressure under daily service is much lower.

The questions of capacity and strength should not be confused with that of economy, and engines should be designed to give their highest economy and should

be tested with the steam and water pressures prevailing in ordinary service.

These, however, are all matters of operation over which the engine builder has no control, and it may be safely said that the duty of every engine under service conditions is proportional to its duty under test conditions, and that a high duty engine has the same relative higher economy over the low duty machine under all circumstances.

The cost of fuel is the item that varies most widely, and although it has been suggested that the average price of coal is such that about 100,000 B. T. U. are obtained for a cent, this can by no means be accepted as a fact, as the greatest factor in the cost of fuel is its transportation, so that coal of high heat value may be obtained at very low cost in the proximity of the mines, while perhaps in another locality, coal of much inferior quality brings a higher price per ton.

If the heat unit basis were practical, it would bring cost of the best grades of bituminous coal, such as West Virginia and Pennsylvania, carrying about 15,000 B. T. U. to the pound, at $3.00 per ton, while the Indiana and Kentucky coals should be about $2.60 per ton, and the Illinois, Iowa and Missouri coals about $2.40.

As a matter of fact, however, the higher grades of bituminous coal cost from $4.00 to $5.00 say in New England; while the same grades of coal can be bought for $2.00 or less in the vicinity of the mines, and in the middle West, lower grades of bituminous coal can be had at from $1.00 to $1.50 per ton.

It being impossible to determine on a general price of coal, it is necessary in every case to make calculations based on the price and quality of the fuel at the particular location.

The writer has long been in search of a boiler that would evaporate 10 pounds of water per pound of coal under actual conditions in every day service, but believes that there is not a single boiler in America doing this to-day, and the boiler plants where the evaporation obtained is better than 9 pounds of water per

pound of coal, can be counted on the fingers—perhaps of one hand.

I believe a fair average for the better plants burning a good grade of bituminous coal is not far from 8 pounds, while the majority of plants, say in the middle West, burning a medium grade of coal, are not doing much better than 7 pounds, and in a very large number of cases where slack or low grade fuel is uesd the evaporation is about 6 pounds.

The above figures are not "from and at 212° per pound of combustible," but are based on the total coal burned to the water actually evaporated into steam at boiler pressure from the normal temperature of the feed water.

In order to facilitate the calculations, instead of speaking in terms of "gallons," it is easier to base the calculations on the water horse power (W. H. P.), this being the theoretical power required to raise a given quantity of water to a certain height in 24 hours.

Table No. 1 shows the water horse power required to raise 1,000,000 gallons per 24 hours to various heights. The figures at the top of the column indicate the feet in tens, and the figures at the left hand side indicate the integral feet between the tens.

Table No. 2 shows in column "A" the duty; in column "B" the steam consumption per W. H. P. per hour corresponding to the duty, and in column "C" the coal per W. H. P. per hour equivalent to the duty shown on the same line; that is, if the duty is guaranteed on a steam basis, column "B" shows the steam consumption per W. H. P., while if the duty is guaranteed on a coal basis, column "C" shows the coal consumption per W. H. P. per hour based on the coal duty shown in the same line. Column "D" shows the tons of coal consumed per year per W. H. P., while column "P" shows the nominal boiler horse power required to supply steam for each W. H. P.

Thus, it will be seen that for an engine having a guaranteed duty of 65,000,000 per 1,000 pounds of steam, there will be required one nominal boiler H. P. for each

TABLE I

THEORETICAL HORSE-POWER REQUIRED TO PUMP 1,000,000 GALLONS IN 24 HRS AGAINST HEADS FROM 50 TO 499 FEET.

FT.	50'	60'	70'	80'	90'	100'	110'	120'	130'	140'	150'	160'	170'	180'	190'
	8.77	10.53	12.28	14.04	15.79	17.55	19.30	21.06	22.81	24.57	26.32	28.08	29.83	31.59	33.34
1.	8.94	10.70	12.45	14.21	15.96	17.72	19.47	21.23	22.98	24.75	26.50	28.26	30.01	31.76	33.51
2.	9.12	10.88	12.63	14.39	16.14	17.90	19.65	21.40	23.15	24.92	26.67	28.43	30.18	31.94	33.69
3.	9.29	11.05	12.80	14.56	16.31	18.07	19.82	21.58	23.33	26.09	26.85	28.61	30.35	32.11	33.86
4.	9.47	11.23	12.98	14.74	16.49	18.25	20.00	21.75	23.50	25.27	27.03	28.78	30.54	32.29	34.05
5.	9.64	11.40	13.15	14.91	16.66	18.42	20.17	21.93	23.68	25.45	27.20	28.96	30.71	32.46	34.22
6.	9.82	11.58	13.33	15.09	16.84	18.60	20.34	22.10	23.85	25.62	27.38	29.13	30.89	32.64	34.40
7.	9.99	11.75	13.50	15.26	17.02	18.77	20.53	22.28	24.04	25.80	27.56	29.31	31.07	32.82	34.58
8.	10.17	11.93	13.68	15.44	17.19	18.95	20.70	22.45	24.21	25.97	27.73	29.48	31.24	32.99	34.76
9.	10.34	12.10	13.85	15.61	17.37	19.12	20.88	22.63	24.39	26.15	27.91	29.66	31.41	33.16	34.93
FT.	200'	210'	220'	230'	240'	250'	260'	270'	280'	290'	300'	310'	320'	330'	340'
	35.10	36.85	38.61	40.36	42.12	43.87	45.63	47.38	49.14	50.89	52.65	54.40	56.16	57.91	59.67
1.	35.28	37.03	38.78	40.55	42.30	44.06	45.81	47.56	49.32	51.08	52.83	54.59	56.33	58.08	59.84
2.	35.46	37.20	38.96	40.72	42.47	44.23	45.98	47.73	49.49	51.25	53.00	54.77	56.51	58.26	60.02
3.	35.63	37.38	39.13	40.90	42.65	44.41	46.16	47.91	49.67	51.42	53.17	54.94	56.68	58.43	60.19
4.	35.81	37.56	39.31	41.08	42.83	44.58	46.33	48.08	49.84	51.60	53.35	55.11	56.85	58.61	60.37
5.	35.98	37.73	39.48	41.25	43.00	44.77	46.51	48.26	50.02	51.77	53.52	55.29	57.03	58.78	60.56
6.	36.16	37.91	39.66	41.42	43.17	44.94	46.68	48.43	50.19	51.95	53.70	55.47	57.20	58.96	60.73
7.	36.33	38.08	39.83	41.60	43.35	45.11	46.85	48.61	50.37	52.12	53.87	55.63	57.38	59.14	60.89
8.	36.51	38.26	40.01	41.77	43.52	45.29	47.03	48.78	50.56	52.30	54.06	55.81	57.56	59.32	61.08
9.	36.68	38.43	40.18	41.95	43.70	45.47	47.20	48.96	50.73	52.47	54.23	55.98	57.73	59.49	61.25
FT.	350'	360'	370'	380'	390'	400'	410'	420'	430'	440'	450'	460'	470'	480'	490'
	61.42	63.18	64.93	66.69	68.44	70.20	71.96	73.71	75.47	77.22	78.98	80.73	82.49	84.24	86.00
1.	61.60	63.36	65.11	66.85	68.61	70.37	72.13	73.89	75.64	77.40	79.15	80.91	82.66	84.42	86.17
2.	61.77	63.52	65.29	67.03	68.78	70.56	72.31	74.06	75.82	77.57	79.33	81.08	82.84	84.59	86.35
3.	61.95	63.70	65.47	67.20	68.96	70.73	72.48	74.24	75.99	77.75	79.50	81.26	83.01	84.77	86.52
4.	62.12	63.87	65.63	67.38	69.14	70.89	72.66	74.41	76.17	77.92	79.68	81.43	83.19	84.94	86.70
5.	62.30	64.06	65.81	67.56	69.32	71.08	72.83	74.59	76.34	78.10	79.85	81.61	83.36	85.12	86.87
6.	62.47	64.23	65.98	67.73	69.49	71.25	73.01	74.76	76.52	78.27	80.03	81.78	83.54	85.29	87.05
7.	62.65	64.40	66.16	67.91	69.67	71.42	73.18	74.94	76.69	78.45	80.20	81.96	83.71	85.47	87.22
8.	62.83	64.59	66.33	68.08	69.84	71.60	73.36	75.11	76.87	78.62	80.38	82.13	83.89	85.64	87.40
9.	63.00	64.77	66.51	68.26	70.02	71.77	73.53	75.29	77.04	78.80	80.55	82.31	84.06	85.82	87.57

ADAPTED FROM HOLLY MFG. CO'S. CATALOGUE.

I.M. REYNOLDS MAY 1891.

TABLE 2.

DUTY, STEAM CONSUMPTION & BOILER HP FOR VARIOUS TYPES OF PUMPING ENGINES.

A	B	P	Q.
DUTY ON STEAM	STEAM PER W.HR PER HOUR	BOILER HR REQ'D	TYPE OF PUMP.
198	10.	0.34	
190	10.42	0.35	
180	11.	0.37	
170	11.65	0.39	
160	12.37	0.41	
150	13.2	0.44	TRIPLE EXPANSION FLY WHEEL ENG'S.
140	14.14	0.47	
130	15.23	0.5	
120	16.5	0.55	
110	18.	0.6	COMPOUND (HIGH DUTY) FLY WHEEL ENGINES.
100	19.8	0.66	
95	20.84	0.69	
90	22.	0.73	
85	23.3	0.78	LOW DUTY COMP. FLYWHEEL & DIRECT ACTING TRIPLE EXPANSION PUMPS.
80	24.75	0.82	
75	26.4	0.88	
70	28.3	0.95	
65	30.46	1.	
60	33.	1.1	
55	36.	1.2	COMPOUND DIRECT ACTING LOW DUTY PUMPS.
50	39.6	1.32	
45	44	1.47	
40	49.5	1.65	
35	56.6.	1.89	
30	66.	2.2	
25	79.2	2.64	
20	99.	3.3	
15	132.	4.4	AIR LIFT PUMPS AND SIMPLE DIRECT ACTING PUMPS.
10	198.	6.6	
5	396.	13.2	

I.H. Reynolds MAY 807

TABLE 3.

STEAM AND COAL CONSUMPTION

TONS OF COAL PER WHP PER YEAR.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
			EVAPORATION										
DUTY	STEAM PER WHP PER HOUR	COAL PER WHP PER HOUR	10	9½	9	8½	8	7½	7	6½	6	5½	5.
198	10.	1.	4.38	4.61	4.86	5.15	5.47	5.84	6.26	6.74	7.30	7.96	8.76
190	10.42	1.042	4.56	4.80	5.06	5.37	5.70	6.08	6.52	7.02	7.61	8.29	9.13
180	11.	1.1	4.82	5.07	5.35	5.67	6.02	6.42	6.89	7.41	8.03	8.76	9.64
170	11.65	1.165	5.10	5.37	5.67	6.00	6.37	6.80	7.29	7.85	8.50	9.27	10.20
160	12.37	1.237	5.42	5.70	6.01	6.37	6.77	7.22	7.74	8.34	9.03	9.85	10.84
150	13.2	1.32	5.78	6.08	6.42	6.80	7.22	7.71	8.26	8.90	9.64	10.50	11.56
140	14.14	1.414	6.20	6.52	6.87	7.28	7.73	8.26	8.85	9.53	10.33	11.27	12.39
130	15.23	1.523	6.67	7.02	7.40	7.84	8.33	8.90	9.54	10.27	11.12	12.12	13.34
120	16.5	1.65	7.23	7.61	8.02	8.50	9.03	9.64	10.33	11.12	12.05	13.13	14.45
110	18.	1.8	7.88	8.30	8.75	9.27	9.85	10.51	11.27	12.13	13.14	14.33	15.77
100	19.8	1.98	8.67	9.13	9.63	10.20	10.83	11.57	12.39	13.35	14.45	15.76	17.34
95	20.84	2.084	9.13	9.61	10.13	10.73	11.40	12.17	13.05	14.05	15.21	16.59	18.26
90	22.	2.2	9.64	10.14	10.68	11.33	12.03	12.85	13.77	14.83	16.06	17.51	19.27
85	23.3	2.33	10.21	10.74	11.32	12.00	12.75	13.61	14.59	15.70	17.01	18.55	20.41
80	24.75	2.475	10.84	11.41	12.03	12.75	13.54	14.45	15.49	16.68	18.07	19.70	21.68
75	26.4	2.64	11.56	12.17	12.83	13.60	14.44	15.42	16.53	17.79	19.27	21.01	23.13
70	28.3	2.83	12.40	13.05	13.75	14.57	15.48	16.53	17.72	19.07	20.66	22.55	24.79
65	30.046	3.046	13.34	14.04	14.80	15.68	16.66	17.79	19.07	20.53	22.24	24.25	26.68
60	33	3.3	14.45	15.21	16.04	17.00	18.05	19.27	20.66	22.24	24.08	26.27	28.91
55	36.	3.6	15.77	16.60	17.50	18.54	19.68	21.02	22.54	24.26	26.28	28.66	31.54
50	39.6	3.96	17.34	18.26	19.25	20.38	21.66	23.13	24.79	26.69	28.91	31.52	34.69
45	44.	4.4	19.27	20.28	21.38	22.66	24.07	25.70	27.54	29.66	32.12	35.02	38.54
40	49.5	4.95	21.68	22.82	24.06	25.48	27.08	28.91	30.98	33.36	36.14	39.40	43.36
35	56.6	5.66	24.78	26.08	27.51	29.15	30.96	33.05	35.43	38.15	41.32	45.05	49.58
30	66.	6.6	28.91	30.43	32.08	33.99	36.10	38.54	41.32	44.48	48.18	52.54	57.82
25	79.2	7.92	34.69	36.51	38.49	40.79	43.32	46.25	49.58	53.38	57.82	63.04	69.38
20	99.	9.9	43.36	45.64	48.11	50.99	54.15	57.82	61.97	66.73	72.27	78.80	86.72
15	132.	13.2	57.82	60.85	64.15	67.98	72.20	77.09	82.63	88.97	96.36	105.07	115.63
10	198.	19.8	86.72	91.28	96.23	101.97	108.31	115.63	123.95	133.45	144.54	157.61	173.45
5	396.	39.6	173.45	182.56	192.46	203.94	216.61	231.26	247.90	266.90	289.08	315.22	346.90

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W. H. P., while for an engine of 130,000,000 guaranteed duty, there will be required but one-half of one nominal boiler H. P. for each W. H. P.

This table also shows the range of duties usually guaranteed for the various class of pumping engines; these duties overlapping occasionally, due to special conditions.

Table No. 3 shows the steam and coal consumption for various duties from 198,000,000 down to 5,000,000; column "A" showing the duty; "B" the steam consumption per W. H. P. per hour; "C" the pounds of coal per W. H. P. per hour, and columns "D" to "N" the coal consumption in tons per year per W. H. P. for various boiler evaporations.

To illustrate the use of this table, assume a guaranteed duty of 170,000,000 per 1000 pounds of dry steam. This would be an equivalent of 11.65 pounds of steam per W. H. P. and if the evaporation of the boiler was 10 to 1 (which it is not likely to be) the coal consumption would be 1.165 pounds per W. H. P. per hour, or as shown in column "D" 5.1 tons of coal per W. H. P. per year.

If, however, the evaporation is only 8 pounds, the coal consumption would be 6.37 tons of coal per W. H. P. per year.

Taking another case in which the duty is guaranteed on coal, say at 140,000,000, then the coal consumption per W. H. P. per hour (column "C") is 1.414 or 6.2 tons per year per W. H. P., as shown in column "D."

In other words, when the duty is guaranteed on coal, it is not necessary to take into account the evaporation of the boilers, but the coal consumption per hour and per year is found directly in column "C" and "D" respectively.

An inspection of this table shows in a rather startling way the meaning of "high" and "low" duty,—taking, say, compound direct- acting pumps at 50,000,000 annual coal duty consuming 17.34 tons per W. H. P. per year against high grade plants having duties of from 130,000,000 to 140,000,000 (as at New Bedford and

Boston) where the coal consumption runs from 6 to 6½ tons per W. H. P. per year.

Plate No. 4 is merely a repetition of No. 3 in the form of a diagram and is self explanatory.

There is no definitely recognized dividing line between high and low duty, but perhaps 100,000,000 duty per 1000 pounds of steam is now generally regarded as the division point, although not so many years ago 100,000,000 duty was considered high.

As pumping engines are special machines and to attain the best results should be built especially to suit the conditions at each location, the price of them is necessarily variable, and the price is not directly proportional to the economy guaranteed and as the price of the fuel varies in every case and the quality of it bears no fixed relation to its price, no unit of value can be established for it. It is these conditions that makes it necessary to consider each case by itself, and to illustrate we will take the case of an engine of 5,000,000 gallons capacity against a head of 240 feet, or a total of 210 W. H. P. (as per table No. 1.)

We will assume that five different engines are offered,—engine "A" being a triple expansion costing $30,000.00 with 150,000,000 guaranteed duty; engine "B" a horizontal cross compound engine costing $20,000.00 with a guaranteed duty of 125,000,000; engine "C" a horizontal triple expansion direct-acting costing $12,000.00 with a duty of 95,000,000; engine "D" a horizontal duplex direct-acting costing $10,000.00 and having a guaranteed duty of 80,000,000; engine "E" a horizontal direct-acting duplex costing $8,000.00 with a guaranteed duty of 65,000,000.

The type of engine however really cuts no figure as we are considering only the cost and duty.

The less economical engines from "B" to "E" will require more boiler capacity than engine "A"; the difference in boiler H. P. required being added to the first cost of the engine at the rate of $27.00 per boiler H. P.

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PLATE No.4

SHOWING COAL CONSUMPTION PER W.H.P. PER YEAR.

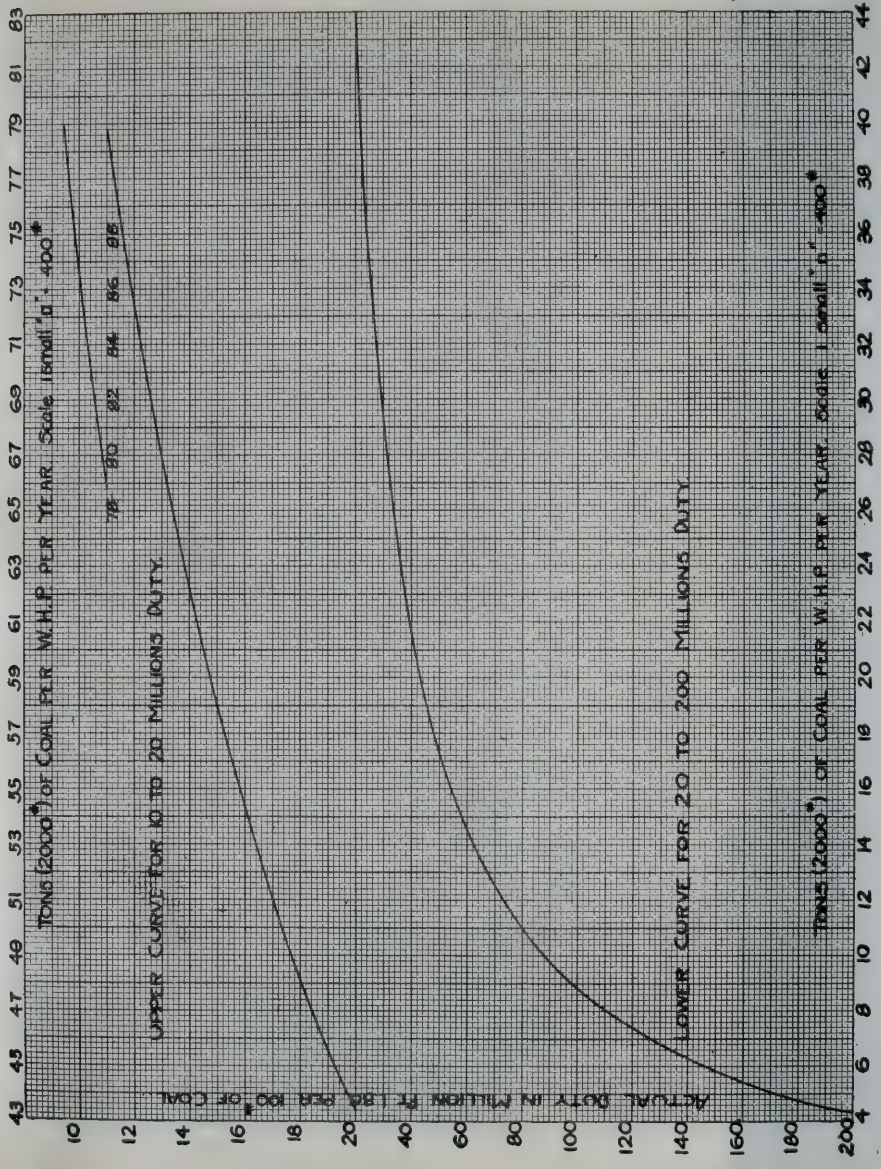
TONS (2000 lbs) OF COAL PER W.H.P. PER YEAR. Scale 1 small "a" = 400 lbs
UPPER CURVE FOR 10 TO 20 MILLIONS DUTY.
LOWER CURVE FOR 20 TO 200 MILLIONS DUTY
ACTUAL DUTY IN MILLION FT. LBS PER 100 lbs. OF COAL
TONS (2000 lbs) OF COAL PER W.H.P. PER YEAR. Scale 1 small "a" = 400 lbs
78
80
82
84
86
88

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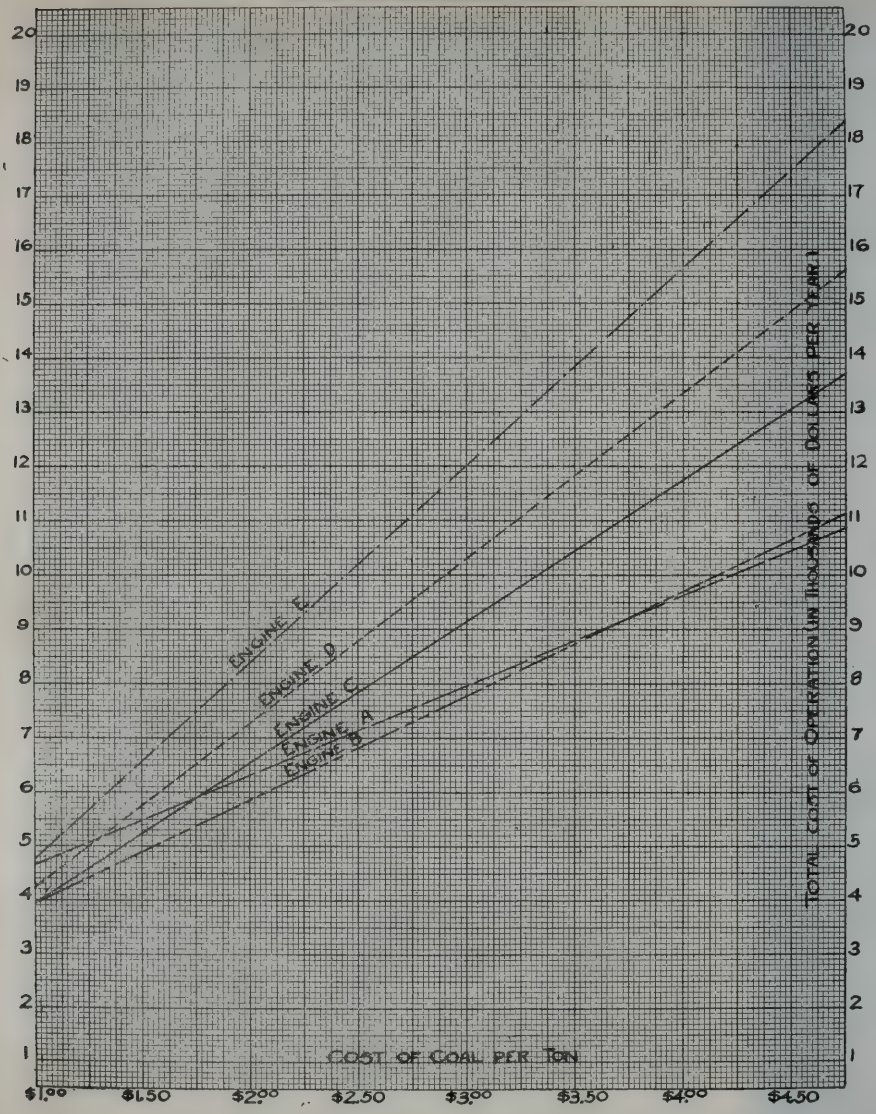
PLATE No. 5

COMPARATIVE COSTS OF OPERATION FOR ENGINES OF VARYING COSTS AND DUTIES.



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pounds of dry steam and for test conditions only, we will assume that under every day working conditions, the engines will only give about 94% of their guaranteed steam duty, and that the evaporation of the boilers is only 8 to 1, which would bring the actual coal duty down to 75% of the guaranteed steam duty.

This figure is rather a high one for most locations, and 70% or even 65% of the guaranteed steam duty would be the more common coal duty.

The cost of operation of each of these engines is made up of two items; fixed charges and coal, the fixed charges covering interest, depreciation and repair, which for the sake of convenience is taken at 10%, although as a matter of fact, 8 or 9% would cover this in most cases, especially on large engines.

With coal at $1.00 per ton, it will be seen that the cost of operation of engine "C" is the least of all—that is $3944.00; engine "B" being practically the same at $3957.00. Engine "A" with the highest guaranteed duty being next to the most expensive to operate, that is, $4655.00 as against the low duty engine "E" at $4746.00.

An examination of diagram (plate No. 5) shows that when the cost of coal increases to about $1.30, engine "A" falls below engine "D" and at about $1.75, engine "A" crosses engine "C" so that at $2.00 per ton, engine "B" is the cheapest to operate, engine "A" next with engine"C," "D" and "E" following.

In fact engine "E" is out of the race altogether unless the price of coal runs below $1.00 per ton, or unless the first cost of the engine could be reduced.

The same is practically true of engine "D'; the race being between engines "A," "B" and "C" up to $1.75 per ton. After that, it is between "A" and "B" until a price of about $3.80 is reached, where the high duty engine "A" crosses "B" and has an increasing advantage, as the price of coal per ton increases.

Of course ,all these lines would change with any change in the first cost of the engines, or with the guaranteed duty. Or, in case the engine was not worked up to its full capacity, either by being operated at

slow speed or only part of the time, then the proportion of coal cost to fixed charges becomes less.

The table, however, shows very clearly that the low duty engine must be of very low first cost and fuel must be very cheap in order to justify its adoption.

For instance, with coal at $3.00 per ton, as shown in table 6, there is a difference of over $4000.00 in the cost of operating engines "A" and "E," which is sufficient to pay 5% on a difference in cost of $80,000.00, or nearly 20% on the actual difference in cost of $22,000.00

With coal at $3.00 per ton, the difference in cost of operation between engines "A" and "C" is $1188.00, or practically 12% on the $10,000.00 difference in first cost.

The duplex pump is a machine beautiful in its simplicity, and its inventor, Mr. Worthington is entitled to the greatest possible credit. As a machine for handling water at moderate speeds, it leaves little to be desired excepting in the matter of economy (and at the time of its invention but little in this particular), but the building of it in the modern triple expansion form has advanced it to as high a position as it can ever hope to occupy while retaining its simplicity.

For handlng small quantities of water where the item of fuel is of secondary consideration, the duplex pump, on account of its lower first cost, has the field, but there is an increasing number of small fly wheel pumps of high and medium duty being built which, together with the increasing cost of fuel will, I believe, ultimately confine the duplex pump to a still narrower field consisting of the smaller sized machines.

The enormous increase in the coal consumption of the country which during the past ten years has doubled, increasing from 200,000,000 tons in 1897 to probably 400,000,000 tons in 1907, (4 tons per capita) precludes the possibility of fuel ever being any cheaper, and I think it may be safely assumed that it will constantly increase in price, and the struggle of the modern engineer is to produce "more power for less fuel," and "if the man who causes two blades of grass to grow where one grew be-

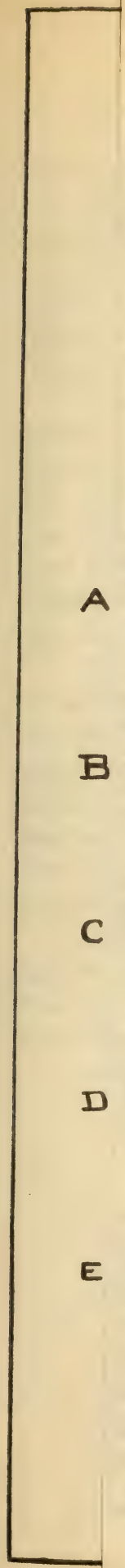
A
B
C
D
E

TABLE No 6.

COMPARATIVE COST OF OPERATION.

5 MILLION GALS., 240 FT. HEAD. 210 W.H.P.

	TYPE OF ENGINE	PRICE OF ENGINE	GUARANTEED STEAM DUTY	ADDITIONAL COST FOR EXTRA BOILERS AT $27 PER H.P.	FIXED CHARGE AT 10%	ANNUAL COAL DUTY UNDER AVERAGE CONDITIONS (75%)	ANNUAL COAL CONSUPTION (TONS)
	ENG "A"	$30000	150 MILLION		$3000	110 MILLION	1655
	" B	$20000	125 "	$460	$2046	95 "	1911
	" C	$12000	95 "	$1400	$1340	70 "	2604
	" D	$10000	80 "	$2160	$1216	60 "	3032
	" E	$8000	65 "	$3130	$1113	50 "	3633
	COST OF COAL PER TON						
		$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50
A	FIXED CHARGE	$3000	$3000	$3000	$3000	$3000	$3000	$3000	$3000
	COST OF COAL	$1655	$2482	$3310	$4137	$4964	$5792	$6619	$7446
	TOTAL COST.	$4655	$5482	$6310	$7137	$7964	$8792	$9619	$10446
B	FIXED CHARGE	$2046	$2046	$2046	$2046	$2046	$2046	$2046	$2046
	COST OF COAL	$1911	$2867	$3827	$4778	$5733	$6689	$7644	$8600
	TOTAL COST	$3957	$4913	$5868	$6824	$7779	$8735	$9690	$10646
C	FIXED CHARGE	$1340	$1340	$1340	$1340	$1340	$1340	$1340	$1340
	COST OF COAL	$2604	$3906	$5208	$6510	$7812	$9114	$10416	$11718
	TOTAL COST	$3944	$5246	$6548	$7850	$9152	$10454	$10756	$13058
D	FIXED CHARGE	$1216	$1216	$1216	$1216	$1216	$1216	$1216	$1216
	COST OF COAL	$3032	$4549	$6065	$7581	$9097	$10613	$12130	$13646
	TOTAL COST.	$4248	$5765	$7281	$8797	$10313	$11829	$13346	$14862
E	FIXED CHARGE	$1113	$1113	$1113	$1113	$1113	$1113	$1113	$1113
	COST OF COAL	$3633	$5450	$7266	$9083	$10899	$12716	$14532	$16349
	TOTAL COST	$4746	$6563	$8349	$10196	$12012	$13829	$15645	$17462

ENGINE-A TRIPLE EXPANSION FLY-WHEEL TYPE.

ENGINE-B COMPOUND, FLY WHEEL TYPE.

ENGINE-C TRIPLE EXPANSION DUPLEX DIRECT-ACTING

ENGINE-D&E COMPOUND, DIRECT-ACTING

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fore is a benefactor" surely the man who makes one ton of coal do the work of two is entitled to equal recognition."

Our civilization of to-day is based on coal and differs in no essential way from that of the ancient Greeks and Romans excepting in the use of fuel,—the principal manifestation of which is in the form of transportation.

Look at the number of enormous power houses, particularly in the vicinity of New York, each of which burn approximately 1000 tons of coal per day; the number of ocean steamers burning from 500 to 600 tons per day, and others building to burn 1000 to 1200 tons, and further consider the fact that power houses, steamships, iron and steel plants, etc. are being built as rapidly as money and men can do the work.

With these figures before us, it seems non-sensical to talk of inexhaustible fuel supplies, for while there are doubtless vast coal areas yet to be discovered, most of them will probably be so far from the present centers of civilization that the cost of transportng the fuel will make its cost enormous, and the time will come when the country which has the fuel supply will control the commerce of the world.

In view of the fact that coal, unlike vegetation, cannot be reproduced, but when once used is lost to us forever, it seems remarkable that any people should be so short-sighted as to frame laws to prevent its importation.

DISCUSSION

MR. HAGUE: I will say that I have been so busy this spring talking about standard cast iron pipe with the foundry people that I have not had much time to prepare any discussion on this interesting paper, but I have been doing some work in the same line as set forth in the paper and it may be of interest to you to know what I have found out in tabulating results. There are several established types of pumping machinery for water works worth considering. The compound condensing low duty engine of the Worthington type. The low duty triple expansion engine also of the Worthington type. The high duty 4 cylinder Worthington engine. The Gaskill 4 cylinder high duty engine, which is a double compound, built compound at each side The cross compound pumping engine, high pressure at one side and low pressure at the opposite side. And the Reynolds Vertical triple expansion engine. So far as I have gone into the question it does not pay to own and operate a low duty compound engine larger than 3,000,000 gallons capacity per day. The low duty triple engine can go to 6,000,000 gallons per day. Above 6,000,000 it is a contention between the cross compound with the two cylinders, and the regular double compound with four cylinders up towards 10,000,000 gallons per day. Above 10,000,000 with coal at $3.00 a ton, with the work at 200 feet head and over, the vertical triple will no doubt take precedence.

In comparing some of these figures I found that a 6,000,000 gallon low duty triple was very much to be preferred considering the capital invested and the running expenses, to the low duty compound. I also found that the 6,000,000 gallon vertical triple with its higher capital account and its lower fuel account was just about on equal terms with the low duty triple; but as soon as the capacity gets above the 6,000,000 line the vertical triple takes the lead in preference. Upon the 6,000,000 gallon line the compound condensing engine would be a better investment under a great many conditions than the 6,000,000-gallon vertical triple. It seems to stand like this: you would

prefer a low duty triple above a compound condensing. You would prefer a regular compound engine like the Worthington or Gaskill above the low duty triple, or a cross compound engine on the same terms, strictly on the figures of cost for installation, but there are quite a number of practical questions to consider in the use of horizontal engines, such as when the river rises and falls a good deal and you have to build a deep pit so as to protect your horizontal machinery; it looks as though it would be better to put your money into the engine in such a case rather than into the building and so have a vertical engine. With the vertical engine it does not matter if the pump end is flooded occasionally with the seepage water which is practically filtered through the masonry and is very clean, and the fly wheels are usually high enough to escape most floods.

The cross compound has lately taken a very strong position but is more or less handicapped by being a horizontal engine in most cases; and the vertical cross compound is usually apt to be a misfit all round on account of various technical details. Of course when we figure the suction lift we must go as high as the delivery valves because the vacuum must be formed up to that level, and with a horizontal pumping engine with its delivery valves high above the floor, and added to that the distance to the water in the well, we get a rather unprofitable suction lift, so that unless you can afford to build a basement to keep the water out from the machinery it would be better to go to the vertical type of engine; then having gone to the vertical type a little more cost will give a triple machine, which gives three plungers, a very uniform flow of water and the very best economy of fuel. However it is very difficult to lay down a hard and fast rule to meet all conditions, in fact such a course is impossible. All conditions must be looked into because sometimes upon going over the ground you find circumstances existing that you could not possibly have anticipated, and it may require a very careful examination before one can see just where the account balances.

In the foregoing comparisons I figured the pumping engines working at two-third capacity, with coal at $3.00 per ton, and an evaporation in the boilers of 8 to 1. By two-thirds capacity is meant either running the engine at full contract speed 16 hours a day into a reservoir, or else running at two-thirds speed 24 hours per day. If the evaporation is below 8 lbs. in the boilers, then the balance will be more in favor of the higher duty machinery because such a state of things is in effect a higher cost of fuel. To say that coal is cheap is a treacherous way of putting the case, because the coal is cheap mostly because it is inferior in quality and the heat units for a cent may be lower than with a more expensive coal. I ran a competitive test once with 8 different kinds or mines of coal, soft coal; the highest priced coal was $4.00 per net ton, and the lowest priced coal was $1.75 per net ton; the highest priced coal did the best from a coal standpoint purely, but its high cost barred it from first place all things considered; the lowest priced coal was extravagantly wasteful of money on account of its low heating capacity per pound; a coal at $3.25 per net ton indicated the best all round economy of purchase and operation. Coal of good quality and low price is near the mines where there happens to be not much water works pumping going on, and where you have to transport long distances the poorer grades of coal have to be charged with high cost of freight per 1,000,000 heat units available. Therefore a moderately high cost of coal a good way from the mining fields, and a moderately high cost of pumping engine, in combination very often shows the best economy in owning and operating the plant. The thing to remember is that low cost of steam is very important, and if an apparently cheap coal causes a high cost of steam per 1,000 lbs. weight, you may be on the wrong premises. Have your coal analyzed. See what its heat unit capabilities are per pound. Ascertain what your heat is costing you. Then from the heat of the feed going into the boilers and the total heat in the steam being made, you can easily find out how much money the steam is costing you. When the cost of steam is known the grade of pumping engine can be readily ascertained.

MR. SANDO: I do not quite agree with Mr. Hague on that division line between low duty triple direct acting and cross compound fly wheel engines, principally for the reason that a very large steel manufacturing concern in the United States has just placed an order for two cross compound fly wheel pumping engines for feeding boilers, capacity of 2,000,000 gals. daily each, the tabulation of prices and operating economy of which was based on business principles, the low duty triples were bigger in every possible way, but the cross compound fly wheel engines proved the best investment. When the engineers of a steel corporation will give that type of engine preference, for boiler feed service, I think it ought to be noticed. But it might be one of those cases where the conditions were just so that they were favorable, and might not turn out the same in regular water works practice.

MR. HAGUE: I think Mr. Sando answers his own proposition—not very difficult to decide that.

MR. N. S. HILL: I am very glad to hear Mr. Hague and Mr. Sando discuss Mr. Reynolds' paper. I am glad to find that we are all coming to a sensible tangible basis in making selections of pumping units. I think it was in May, 1905, or a little before that time I prepared an article for the Engineering Record, in which I took the stand that the selection of a pumping unit really had little to do with the type of engine. In other words, that the selection of the type of engine should be governed by the conditions under which the engine was to work; that to prescribe a vertical high duty crank and fly-wheel pumping engine as the only specific for all conditions was a mistake; that the actual conditions of operation were to be considered by the superintendent rather than the special efficiency of the machine; in other words, that for operating purposes the duty per 100 lbs. of coal indicated more than the duty per 1,000 lbs. of steam; or rather, that while the engine test should be made on the steam basis, under running conditions, the total cost of the operation of the plant was the thing which interested superintendents most, and this included not only the operating cost but fixed charges, depreciation, and other

things as well. It pleases me very much to see these charts and curves and information showing that there is discretion to be used in the selection of pumping engines.

PRESIDENT MAURY: If I may be allowed to add something to this discussion, I should heartily endorse Mr. Hill's statement that conditions should in every case govern the selection of a particular engine. In further corroborating Mr. Hill's views, I would say that the study of conditions should take into consideration the station duty, and not under any circumstances the test duty; furthermore, and along the same line, it should always be borne in mind that in no water works pumping station, any one engine is ever going to be able to operate at its full normal capacity 100 per cent of the time. Therefore, in apportioning the charges for or against any one type of machine some estimate should be made as to just what per centage of the time, and at what average rate, or average percentage of its normal rate, the pump which is selected will be called upon to work during its entire lifetime; I believe that that consideration is oftentimes neglected, and that estimates are based upon the wholly erroneous assumption that the pump, once set up, is going to run right along, at full speed, till it is relegated to the scrap heap. Something further should be done, I think, in reaching a fair basis for an estimate—it can only be an approximate one—as to the number of hours the pump is going to actually be called upon to run during its lifetime, and an approximation to the probable rate at which it will be called upon to run; that, of course, brings it right back to the question of station duty.

MR. HAGUE: Your remarks remind me of something which I omitted to state; that is, that I figured on two-thirds of the capacity, with coal at $3.00 a ton, boiler evaporation 8 to 1, which can be obtained with proper care and attention to the machinery, either running the engine at full speed into the reservoir 24 hours per day, or running two-thirds capacity; but 8 lbs. evaporation ought to be obtained anywhere with conditions right and the boilers

rightly proportioned to the work; and with two-thirds capacity we will get a very good per cent, I think, probably as good as can be gotten without special investigation.

MR. MAURY: Right there, I should like to emphasize my small contribution to this discussion by saying that whether the two-thirds capacity be the percentage of work that should be assumed as correct, or whether it should be only one-fourth of the total time is a question which must be determined by a study of the local conditions. If we take the average direct pressure pumping plant without reservoirs, we find that the maximum hourly rates of pumping are very much more than double the normal rate of pumping, and the station must have something in reserve. Such considerations might reduce the total percentage of the time of the working of an engine in a particular case considerably below Mr. Hague's percentage of two-thirds. On the other hand, if you consider the case of a city which has reservoirs and a large number of pumping stations, and a number of engines in each pumping station, then I can conceive that Mr. Hague's estimate might often be too low; but I think the whole question comes straight back to the original proposition that it is the station duty that has to be considered always, and that a full allowance should be made for the loss of time in the actual working of the engine.

MR. N. S. HILL: I think this discussion brings out a point which is too often neglected in pumping station design; and that is the subdivision of the pumping units to suit the variation in load. It is a common water works practice to take the maximum total pumping capacity required and subdivide this into pumping units of equal capacity; that is to say, if there are 100,000,000 gallons a day to be pumped it is usual to install say five 20,000,000 gallons pumps. It might develop, however, that a subdivision of these units into different sizes would allow for more economical operation than would be otherwise possible. With a due consideration of the load factor on the station and the hourly variation on the quantity of water to be pumped it is not uncommon to find that a little figuring will show that by an intelligent subdivision of units the station may

be worked at its maximum efficiency throughout the 24 hours. I have found that by using a pitometer in the same way as an amemeter is used in electric stations, you can collect a great deal of valuable informaton which is useful in enabling you to subdivide your units to suit the most economical conditions of operation.

MR. CHESTER: The paper in my opinion contains a great deal of value, and the only differences I have with its author are as to where certain lines should be drawn; and these differences I am going to attribute to my more extended experience in operating pumping engines than that possessed by the author of this paper. I shall not attempt an equality with him in the designing of pumping engines, but as aforesaid, only as to experience in their operation. The first table, as he quotes it, "adapted from the Holly Manufacturing Co.'s catalogue," is handy for reference; and before passing it over, but not connecting it particularly with what I have to say later on, I want to suggest a means of using this at any time without carrying it along with you. If you will go into this table at the point where a million gallon rate is discharged against 100 lbs. pressure, you will find it gives you about 41 HP., and carrying that figure along you will always be able to use this table, for, of course, any fraction of a million gallons is that fraction of 41 HP., and any amount over is a multiple; also any pressure over or under 100 lbs. would be a fraction or multiple of 41. To table No. 2 I want to take some exceptions. In one of this morning's papers I found a very neat advertisement following the account of the Convention, in which we were told that the record for high duty was made at St. Louis, and is over 180 million. Mr. Reynolds in table No. 2, in laying out his braces, the top one being for "triple expansion fly-wheel engines," has extended the top brace clear to the limit. When he reaches the "cross compound fly-wheel and direct acting triple expansion pumps," he stops his brace at 95 million. I know from experience and actual tests made that if Mr. Reynolds, or any one else, will give me conditions that will permit a triple expansion crank and fly-wheel engine to produce a duty equal to the amount shown by the top of his brace, let that

be what it will, I will take the same conditions with the so-called low duty triple.—I object to that title being applied to this engine—and produce a duty of over 110 million gallons, and consequently I would ask that the brace for the direct acting triple be extended up at least two spaces, and it might be two spaces and a half.

Now I am taking up these corrections in order that I may later on correct some of the conclusions that have been drawn from the data tabulated and get the matter square before you—as you all know Mr. Reynolds is a designer and builder of triple expansion and cross compound fly-wheel engines,—I was for many years an operator of all kinds, and I am now a builder of triple expansion direct acting and cross compound crank and fly-wheel engines. So you may attribute my criticism to my present position, but in defense of this and of my appearing here I refer you to the transactions of the American Society of Civil Engineers of 1903, or the St. Louis Congress, at which I read an argument on Mr. Reynolds' paper there, and at which time I laid down the same principles to which I adhere to-day, and expect to adhere for many years. The main difference between Mr. Reynolds and myself is that he would extend the field of the triple expansion fly-wheel engine to a much lower HP. than I think warranted. I like to express it in horse power instead of gallons, because it is not gallons delivered, it is HP. and cost of coal that draws the line. He also extends the range of fuel to a much lower price on coal than I would. The field that Mr. Reynolds gives to the compound direct acting and the air lift pumps, in both cases I would want to move the brace down a little.

The one thing that I have been trying for years to drum into the author of this paper, and you see he has positively refused to consider it—other than where he tried to checkmate me in what I am about to say now, when he put in one little clause here which reads—"Of course all these lines would change with any change in the first cost of the engines, or with the guaranteed duty, or in case the engine was not worked up to its full capacity, either by being operated at slow speed or only part of the time,"—that is

the meat of the cocoanut. If Mr. Reynolds had put that paragraph first, and worked out his duty and drawn his conclusions on engines working to full capacity only part of the time, his tables would have been of far more use to the members of this association than they now are. I believe that nine-tenths of the superintendents who observe the operation of their machinery and who pump 5 million gallons or less, operate not at full capacity, not at two-thirds; but if they take the total water pumped per annum they will find it is more nearly 50% than it is 100% or even 75%. Therefore, in attempting to analyze and apply duty guarantees to actual conditions, we have got to say not only what the duty is going to be, but the speed and annual pumpage of the engines and what is the relative value of interest and depreciation coupled along with the duty actually performed.

To reinforce my statement, in some 40 plants operated by the American Water Works & Guarantee Company, I do not believe there were five where the engines were permitted to run at 24 hour stretches at full speed. These engines were in the main of less than 5 million capacity. Five millions was a favorite unit, and some of you who live from Pittsburg east, or where the contours of the country are a little more irregular than from Pittsburg west, will appreciate that after you leave the foothills of the Alleghenies and start west over the immense plains and agricultural districts, and it is the same in Canada, you will find few places where you can build a high level reservoirs. Then you are lucky if you have a standpipe. Your standpipe is only a relief valve against which you can pump as an equalizer, but you must operate your pump against the consumption. And having only the standpipe for storage you must provide capacity for fire service. Your consumption say is 3 million gallons and the capacity of your engines 5 mills. If about 2 o'clock some morning you will wake up and examine your pumping station you will find that your pump is operating at less than a one million rate. Then if you visit that pumping station at 6:00 o'clock p. m. in the summer time when the sprinklers are going you will find that engine going along at pretty near a four million

rate, and then if they happen to turn in a fire alarm it may be sometimes forced up to 6 million, exceeding its capacity. (I have seen one at Portsmouth, Va., get up to a 7½ million rate to take care of a fire.) You will then realize that you cannot figure your water horse power on the full capacity of your engine, and you who buy your engines on these per cents are going to buy a misfit, something that you cannot use and that is not going to be the best investment; and until you analyze your service and realize that that engine has got to work at all sorts of speeds and all sorts of duties you are not going to make an intelligent purchase.

At a Water Works letting in a Rocky Mountain city this spring, where they asked bids on 5 and 10 million gallon engines, the engineer had made up his conclusions as Mr. Reynolds has made his, but after a careful analysis figured out that that engine would only pump 23½% of its rated capacity during the entire year, or for six months of the year they would stand absolutely idle, then for four months, for four hours a day they would run full speed, and for two hours half speed; for two months they would run half speed for four hours. When all was figured out the pumping as aforesaid came to 23½% of the rated annual capacity; so instead of figuring his W. H. P. hr. on the full capacity of the engine, he took 25% of the capacity, and while his first figures had put the higher class and higher cost engine first in his list, when he took 25% of the capacity of the W. H. P. per year, it put the cheaper engines No. 1 in his calculations and finally his recommendations, consequently it meant the purchase of that type of engine. In another instance,—the superintendent is here and can vouch for it—they had a high duty engine. It was a good machine and in good repair and able to do good service. It, like all other machines made by man, was subject to breakage occasionally, and having no duplicate they thought to buy one, and they advertised. The advertisement described very closely a duplicate of what they had, but when the bids were received and analyzed, and they considered the fact that they need only run this engine 30 days out of the year while the other engine was being repaired,

they found they could not afford to put the price of the second engine equivalent to the first one they had. They could buy a cheaper machine, because when they took the W. H. P. for 30 days instead of one year and the interest and depreciation piled up so, they acted wisely and purchased a direct acting triple. I could review Water Works contracts indefinitely but will ask you individually as superintendents to go over your conditions, do you run your pumps at full speed? Does any pump you have got give W. H. P. for one year as Mr. Reynolds has tabulated it in his tables and asked you to use those tables in the future selection of your engines? I believe you will stand up and say, no. Even you that are running 15 to 20 million gallon engines that are running into mains that are equivalent to reservoirs, where you start and run the engine full speed until shut down, do you think that your engines will average 365 days of the year? If they do you better buy some more engines. Not only are the first cost, and consequent depreciation and interest charges, going to be high on your higher priced engines, but there is another feature, you are going to have to pay more for your engineers, you are going to pay more for your oil, packing and waste. When it is all properly calculated and tabulated, if properly interpreted there will be more of you buy simple engines instead of complicated ones.

Now with due respect to the municipally owned plants, there seems to be a marked dividing line when it comes to the purchase of engines. You go and visit the privately owned plants of this country and you will find that engines of a certain H. P., where coal is the same price, are in the majority of cases of lower type and cost than in the municipally owned plants. The men who own such plants look for an actual return in dollars for the service they are giving. On the other hand, in municipal plants there is a political body who like to see the wheels go 'round, who like to see a more showy engine, when they buy an engine some of them like their names on it and like to look upon it in after years as a monument to their term of office. In such

a plant you will always find a higher type of engine for the same H. P. and same price of coal. That is all very well, I am not criticising it.

Ten to fifteen years ago when I was traveling for Henry R. Worthington we put out the first triple expansion high duty engine at York, Pa. Our friend Mr. Hague was engineer of that plant. We of course were proud of our first product. We took a great deal of pains to get a photograph of that engine, and naturally we put everything on the engine that we were going to have on it in the way of indicator pipes, oil-cups and things of that kind, before we took the photograph. It made a pretty good looking photograph so far as complications were concerned. These photographs were printed and some of them enlarged, and the representatives of the concern carried a supply of them when they went out to sell waterworks machines. One of the first encounters I had was with Mr. J. H. Purdy, now General Manager of The American Water Works & Guarantee Company. When I laid down my photograph he looked at it, shook his head, and said, "No, John, that is too complicated." I tried to argue with him, told him that it had only two more cylinders than a compound and was not any more complicated than the other, but I realized our mistake in taking that photograph. I went back to the factory and told my troubles, and said, "Now I want a photograph of an engine with only the bare valve motion on it, I do not want a single indicator or other fixture." We got up a new photograph, and I started out again. This time I went to a municipal plant. They called for a high duty engine. When my turn came to talk to the Council I laid my photograph down and showed them how simple it was. When I got through one old fellow said, "That don't look nothing like a pump, that don't suit me." Then I saw I had made a mistake again. But I got a line on what I had to do, that was to use the simple photograph when I was selling to a private plant, and the ornamental one when I was selling to a municipal plant.

In regard to the matter of depreciation, the matter of repairs, the matter of wages, some time ago I came across

a newspaper that published the annual report of a water department in a city not a thousand miles from Pittsburg.

Fuel bill for the year,	$25,700.00
Repairs for the year,	21,372.00
Wages for the year, (at station)	21,783.00

Now, gentlemen, if any of you were endowed with the responsibility of bettering the condition of that plant, would you begin on the fuel bill? When you realize that the cost of pumping water with high duty engines in this country is about ½ cent per 1000 gallons—5 mills per 1000 gallons —that the total cost of pumping water at such plants is about 3 cents a 1000 gallons, you will readily see that the fuel bill is 16 2-3% of the total cost of pumping the water, yet nine-tenths of the papers that are read to us on reduction of cost of operating waterworks are along the lines of trying to trim another mill off the 16 2-3%, and neglect the balance of the 100%. If we can get some more information here on how to trim down the 83 1-3%, and let the 16 2-3% rest for a while, I believe that you will all go home with new or better ideas of how to reduce your operating expenses. One way is by simpler engines, cutting down the cost of your interest, your depreciation, your replacement cost, your engineer's hire, and your oil, packing and waste bills. Now I do not say what kind of an engine to buy. That must be governed by your H. P., price of fuel and general surroundings. The cost of fuel for pumping water with the high duty or triple expansion engine being about 5-10 of a cent per 1,000 gallons. Allow for argument that the cost with the lower class of direct acting engines is going to be in the neighborhood of 1 cent, or 10 mills instead of 5, you say therefore that the cost of pumping your water is going to be something more than 3 cents per 1000 gallons. Not at all, it does not follow. I have the records of seven years' operation of 40 plants, showing that the operation of the lower class of machinery properly selected is in the end just as cheap as the higher class.

MR. SANDO: In the absence of Mr. Reynolds, the author of this paper, I feel that something ought to be said for the fly-wheel engine. The criticism has been quite severe.

Mr. Reynolds does not undertake to dictate to anybody what type of engine they should buy. He simply gives a tabulation of figures which are based on facts, and you can select your own engine, you can do your own figuring. He gives the evaporation in table No. 3 from 10 pounds down to 5 pounds, and the duty on steam from 198 million. down to 5 million. Probably the reason Mr. Chester and Mr. Reynolds differ in their opinion of duty is because Mr. Reynolds has tested engines, also tests have been reported by unbiased engineers all over the country; these duties have been reported by different engineers, not by the same ones all the time; we have no records of that kind for the duties of these low duty triple direct acting pumping engines. It would be of immense value to the members of this Association and to manufacturers generally to have records of that kind by engineers of reputation. I think that we would all welcome such information.

Mr. Chester says that he has the records of 40 odd stations for the last 17 years, and he quotes you what it costs to pump water according to figures that he carries in his head. Why not get these costs up in the form of a paper to be read before this Association, so that we will all know, so we can have all the links together and there will be no missing link. Then we can get at the thing better and with some certainty.

Mr. Tarr: I am glad to see that the pump builders are coming up here to instruct you in regard to the machine you ought each to have for your service, but it is curious how our professional ideas and our professional knowledge are biased by the type of machine we are building.

Mr. Chester's remarks are exceedingly interesting but he does not go far enough. He would have you make one type of engine do every one's work and do it better than any other type. There is no one type of engine that is best fitted to all conditions. You cannot double up cylinders and do the imposible more than a man I once ran across down in Bethlehem.

They were having some trouble with their pump and I went to the station and found that while everything was all right, it would not do the work, would not lift the load. I asked the engineer how much steam he had on. He replied one hundred and twenty pounds. There was a mystery, for the engine was amply large for the work with this steam pressure. I then went into the boiler room and found that the gage recorded sixty pounds. I said "Why man! you have only sixty pounds of steam, not one hundred and twenty." He replied "Don't you see I am working both boilers, and isn't twice sixty one hundred and twenty?"

I shall not attempt to instruct you only to give you a bit of fatherly advice.

As I told you last night, I have been selling you people pipes, pumps and all sorts of things for forty years, at least some of you, and I want to say, as a result of long experience, that the only way for you to determine in the selection of the proper engine is for each to study his own conditions. Do not take anybody's word for it. Don't place too much reliance upon published official tests. I know a great deal about official duty tests and I remember in the old days when there was sharp competition between types of engines that we hired a man who was of no possible use for any other purpose, because he could make a pound of coal go further under a boiler than any other living man. Now of what value is a test made under these conditions, or any others than your own? There is nothing that has been published that will tell you how to get more money out of your plant than you know yourself, if you will give it careful investigation. In very many cases it is a fact that what we call a low duty engine is the very best purchase. You cannot afford to put your money into a great big high cost engine unless the quantity of water pumped annually is large and coal high. In other words, you want to get a new dollar for an old one. Examine engines that are running under conditions similar to your own. Study the operation of the highest class of engine working under these conditions, and find which of them is pumping annually the most water with the least fuel. That kind of observation and

study would be worth more to you than all the books published, and if opened up they would make a pathway from here to the Atlantic ocean.

MR. REYNOLDS: (Closing discussion). In the discussion of my paper I note that stress is laid on the necessity for considering the actual conditions of operation in each case. This being particularly true of Mr. Hill's and President Maury's remarks.

I realize the importance of this and mention it specifically in the third paragraph, page 212 and throughout the paper call attention to the effect of variation in the different factors (see particularly the last paragraph, page 205).

"As the conditions surrounding the operation of pumping machinery vary widely, it is not possible to lay down any hard and fast rule for determining the most advantageous type; it being necessary to consider each case by itself but it is the purpose of this paper to call attention to certain of the more important points involved in reaching such a decision."

As the calculations must be made for each individual case the tables are offered as matters of convenience in making such calculations.

Mr. Maury suggests that, "No one engine is ever expected to operate at its full normal capacity 100 per cent. of the time." This is true of small water works plants, but in many cities where the water consumption is high and a number of engines employed it is possible to operate them at pretty nearly their rated capacity practically through the year. I have particularly in mind an 18 million gallon engine in the Milwaukee Water Works which has been in operation for about 15 years an average of 23 hours per day at full rated capacity or above. For one year it averaged 23-87/100 hours per day at 10 per cent. above its rated capacity and another year 23-74/100, and during all this time the engine has had practically no repairs, such slight ones as were necessary being made by engineers of the station. While this is an exceptional case there are many large cities which have records approaching this, but whether the consumption be much or little a high duty engine always gives relatively high economy as compared with a low duty engine. While engineers can build machinery to give economy through considerable range of capacity yet

the judgment in securing this machinery must be exercised by the Water Works Managers, and the matter of station economy is almost entirely within their hands.

Replying more specifically to Mr. Chester I would say that the differences of opinion which he suggests are doubtless due to the fact that most of his life has been devoted to the advocacy of direct acting pumps, while my efforts have been largely directed toward developing the fly wheel engine. Most of the arguments which Mr. Chester puts forth I think he will find answered in the original paper itself if he will carefully read it.

In bracketing the duties in Table 2, I have merely included the duties usually guaranteed or often reached, and I state (page 211) that these duties occasionally overlap, in fact the compound high duty fly wheel engine is bracketed at 120,000,000 as a maximum, while builders are guaranteeing above 130,000,000 for this class of machines, but I have not seen any guarantees above 95,000,000 for direct acting triples of Mr. Chester's manufacture, but if he has facts which warrant the moving of the brackets he is at liberty to do so.

The gist of Mr. Chester's argument I take to be that direct acting pumps could be advantageously used in many cases where fly wheel pumps are generally considered better and that the high duty pump is more expensive to operate in all particulars except in the matter of fuel. The purpose of my paper was not to advocate any particular type of pump (see second paragraph from bottom of page 212), but to give water works managers a clear understanding of the factors involved, and if the engines are to be operated at half speed or any other speed it is only necessary to base the calculations on the HP. of water actually pumped, which is the exact purpose for which table No. 1 is intended. If I follow Mr. Chester's argument it is that the low duty pump is preferable because pumping engines are often run very much below their capacity. "Reasoning on this basis it follows that direct acting pumps are most economical *when not in use.*" This may sound like sarcasm, but it is not so intended, for the determining point in the choice of engines is the ratio between the first cost of the machinery

and the cost of fuel to operate it. This naturally leads to the use of engines of low first cost for intermittent work and causes a retention of old low duty engines as reserves in some very modern pumping plants. Mr. Chester speaks of a plant in the vicinity of Pittsburg where the cost of fuel is only about one third of the total cost of operating the station, but if a similar plant were located where fuel is higher, the figures might easily be reversed, the cost of fuel becoming two thirds of the cost of operation. Leaving out the repair bill which is abnormally high, and which must be due to some special circumstances, what would Mr. Chester do to reduce the cost of operation? Would he put in direct acting pumps (he objects to the term low duty), thereby increasing the fuel consumption? Mr. Chester twice mentions the greater cost of attendance, oil, supplies, repairs, etc., for high duty engines, but I know that it cannot be shown as a general proposition that the cost of maintenance of fly wheel pumping engines is greater than that of direct acting pumps on similar service; in fact, I believe that the contrary is true. Of course, there are occasional instances where repair bills have been very high, but this is true of both classes of engines, and I can cite a great number of cases where high duty fly wheel engines have run for periods of from 10 to 20 years, practically without repairs. As to increased cost of attendance for engines of a given size, no larger number of men need be employed nor need they be of higher skill to handle the fly wheel engine. Mr. Chester was for some years engaged in the operation of pumping plants, and I am sure, that a paper by Mr. Chester, as suggested by Mr. Sando, giving the statistics of various stations which were under his charge would be of the greatest possible interest to members of this Association, and I trust we may have the pleasure of having his figures and facts in a concrete form at an early meeting of the Association.

PECULIAR INSTANCE OF CONTAMINATION OF A WELL WATER.

Dr. W. P. Mason.

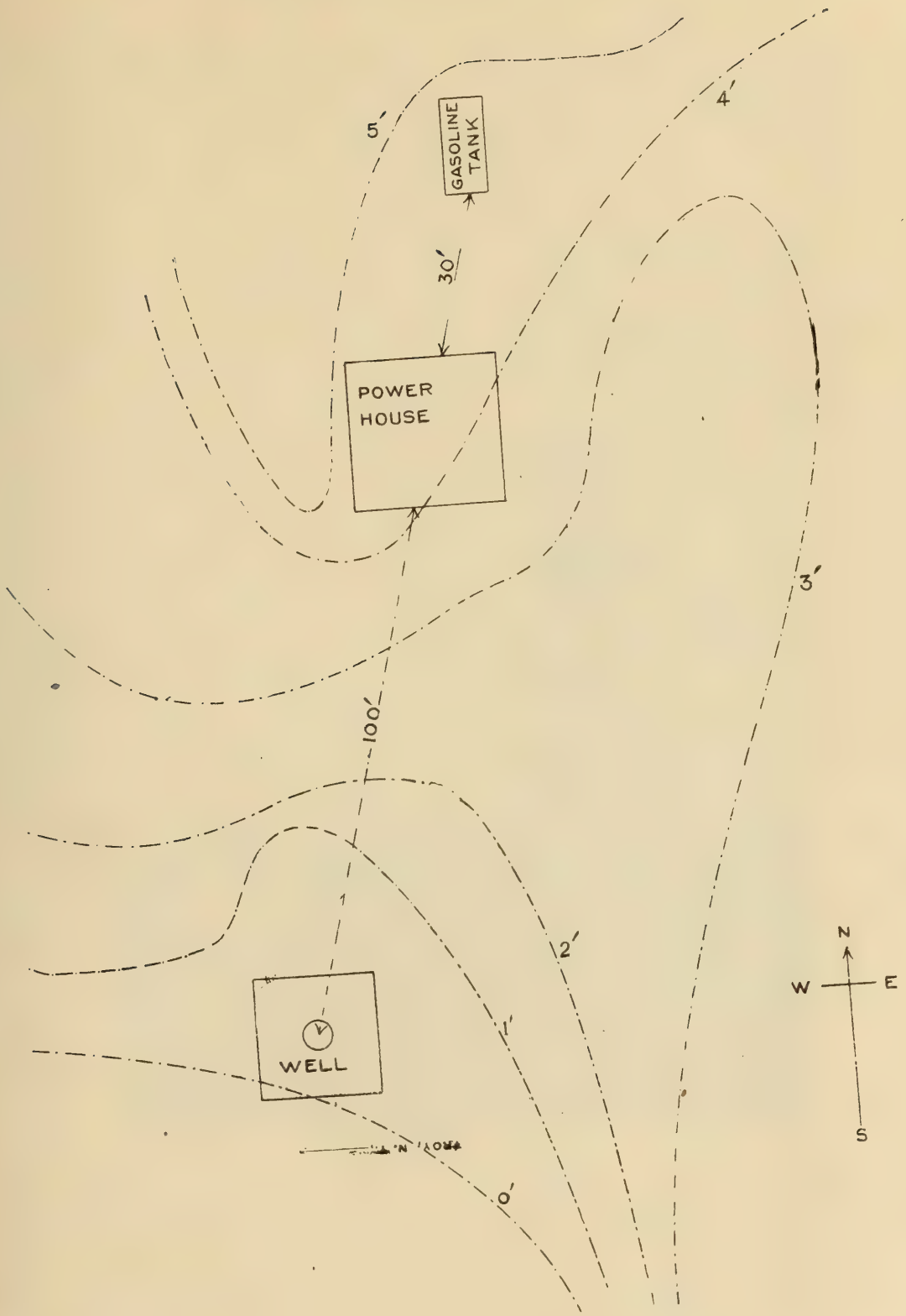
The Anti-Tuberculosis Association of Wellingford, Conn., possesses a six inch well drilled through red sand-rock to the depth of sixty-six feet and water raised therefrom by wind-mill was formerly of excellent quality. During the Summer of 1904 an electric light plant was erected, which was supplied with power from a gasoline engine. The necessary store of gasoline was contained in a cylindrical tank of riveted steel, three feet in diameter and ten feet long. This tank was buried just under the ground surface at a point 130 feet distant from the well, and two gasoline engines were installed in a power house nearer the well by thirty-feet.

About one month after the starting of the engines, a very decided taste and smell of gasoline developed in the water of the well and has continued, although with diminished intensity, to the present day, nearly three years after its first being observed.

The contour map indicates the relative positions of the well and the gasoline tank, and shows the general slope of the surface towards the well. The dip of the sand-rock is practically in the same direction.

A suit for damages having been inaugurated, I was requested to examine the property and to advise as to the probability of the well being able to recover its original purity within a reasonable length of time.

The information furnished me showed that whether from the exhaust of the engines, from a faulty connection or from a leak in the tank itself, several hundred gallons of gasoline had run on to or into the soil within about 100 feet of the well. My opinion was that the injury done was be-


5′
GASOLINE TANK
4′
30′
POWER HOUSE
3′
100′
1
2′
1′
WELL
0′
N
W
E
S

yond repair and that the well should be abandoned for drinking purposes. When one bears in mind the minute quantity of kerosene which remains upon the hands after handling a lamp and with what certainty a pitcher of ice-water is caused to taste of the oil if the ice be touched by the hands so

soiled, it is easy to appreciate how very far several hundred gallons of gasoline would go towards contaminating a ground water.

The correctness of the opinion as expressed above has been borne out by the persistence of the gasoline taste in the water until the present time.

Of course the day will come when the last trace of oil shall have been washed away, but who would venture to fix the date for its accomplishment?

DISCUSSION.

DR. W. P. MASON: There are one or two little side matters that came up which might possibly be interesting to you. The well was contaminated by gasoline leaking from a tank which had been shown capable of standing at least five pounds air pressure. The amount of pressure coming from the gasoline was surely much less than five pounds, because the tank was only three feet in diameter. Let us call it a pound and a half. The opposing side attempted to show that a tank which would stand five pounds air pressure without leaking would leak under a pound and a half liquid pressure. That I doubted, and I ask the attention of the Court to that time-worn experiment, where we pass gas through a porus plate through which water will not pass. As another illustration I asked his Honor's attention to the fact that when beer is to be pumped from the cellar to a spigot by the ordinary beer pump, in a certain number of cases the barrel will not hold the necessary pressure when the bar-tender couples on his air pump. Now, in such a case, the barrel, although it holds the beer will not hold the necessary amount of air pressure to carry the beer to the faucet, up stairs. His Honor was pleased to state that I showed a very considerable amount of familiarity with the illustration.

I think I have covered the only points of interest which are worth mentioning in reference to this small case which I have reported because of its oddity. I invite your attention to this further point, viz.: the hopeless character of the contamination. If you get ground water contaminated with a mineral product such as petroleum oil, you cannot hope for speedy relief, and you would do better to abandon the source of supply for a new one.

MR. MAURY: In the State of Illinois there once flourished a Health Officer who was afterward mayor of the town in which he lived. He wanted to get a water works plant and a sewer system put in. His shrewed common sense and other virtues have resulted in his promotion to the responsible charge of one of the largest charitable institutions in the state. Just after the close of his term as

mayor in describing his troubles in installing water supply and sewers, he said that the citizens objected to the improvements because they were perfectly satisfied with their cisterns and believed that they would not leak. He was equally convinced that the cess pools did leak into and contaminate the cisterns. He thought it was useless to try and convince the objectors by words, and so, one night he sent a man around and had him dump a gallon of kerosene in every cess pool and the next morning everybody was tasting kerosene in the cistern water.

BRISBANE AND ITS WATER SUPPLY.

Allen Hazen.

Brisbane is the capital and largest city of Queensland, and is the actual commercial center for the southern and most populous part of that state. A series of smaller cities on harbors, scattered along the northern coast, serve as centers for the regions back of them, and they have their own connections by steamer with the outside world and only in a very general sense are these smaller centers tributary to Brisbane.

Under the circumstances it is remarkable to find a population of 130,000, or one-fourth of the entire population of Queensland, in Brisbane and its immediate suburbs, and this is the more remarkable as there is but little manufacturing. Such a concentration of population would be hardly possible in a colder and less friendly climate, and the best explanation for so large a population in the capital city is found in the cheapness, ease, comfort and advantages of the city life, which make it attractive to thousands of people of moderate means, who under other circumstances or in another climate would live in the country.

Brisbane is already a large city for the population and development of Queensland. She is sure to be some day many times larger. This will come about through the development of the great natural resources of this country of perpetual summer, which as yet remain without being utilized to an extent that is hardly conceivable to one used only to American and European conditions.

Queensland has an area of 668,497 square miles, equal to that of all the states east of the Mississippi excepting Ohio, Indiana and Illinois. Of this area I saw only that which could be seen by traveling a few hundred miles in a corner of the state. This little part is, however, the most highly developed part of the state.

Even in this little area about Brisbane which I saw, there are thousands of acres of magnificent hard-wood timber, destroyed and in course of being destroyed (without saving any part of the lumber) for the purpose of making better pasture for the stock, and thousands of square miles of land, level, smooth, fertile, and capable of growing two crops of Indian corn per year or other crops in proportion, and not under cultivation at all but only used for the grazing of cattle.

It is true no doubt that the grazing is very profitable, but it seems like a very inadequate use of the land.

The sheep country is farther back from the coast, for the sheep do better in a rather dry climate. The artesian water there available is often comparatively saline for hu-

man use, but the sheep do well upon it, and its discovery and use has been a tremendously important element in the development of a great region of splendid resources, but where the surface and shallow sources of water often go dry.

The average rainfall in Queensland, as shown by 144 stations maintained by the Government, ranges from 4.86 inches at Kallidiwarry in the extreme western part, to 144.05 at Geraldton, on the coast. At Brisbane it is 48.93 inches, and almost everywhere the average rainfall seems to an American sufficient. But some parts of Queensland are very dry, and nearly all parts are too dry at times.

This is partly because of the great evaporation in the

warm climate, and with abundant vegetation growing all the year round, which requires far more water than would be required in a cooler climate, and in part to the very irregular distribution of the rainfall. Very heavy rain falls occur occasionally, while at other times there are years when the rainfall is far below the average. The occasional droughts are the one great obstacle to the development of the State. But the obstacle is not unsurmountable. Much can be done to avoid the trouble coming from this shortage of rain.

Up to the present time the squatter or station owner has been from the nature of the case a gambler. A few good years served to make him wealthy, a few bad ones, to ruin him. The effect of a dry year extends far beyond

the actual dry period. It means a shortage of feed, and a loss of stock resulting from this shortage. The loss is a dead loss because the stock is not marketable at such a time. The loss as far as I could learn always comes from shortage of feed, not from shortage of drinking water. Drinking water for the stock is always available from the water-holes in the streams, which never go entirely dry, though the streams very frequently cease flowing, and in the dry western country there are the artesian wells, unaffected by drought, which always can be relied upon.

Already a few stations are building silos and raising crops to fill them in years of plenty to feed the stock in years of drought. Only a beginnng has been made. A thousand times more can be done with advantage. It may not be possible to make the stock actually remunerative in a dry year by such feeding, but if they can be kept alive by giving them half rations at such a time, the herds that are so carried through and are able to take full advantage of the splendid feed and high prices which follow will surely earn large profits to their owners.

Better means of transportation for both stock and feed would also do much to improve conditions.

A few station owners fortunately situated have practiced irrigation in a small way, and so have carried their stock through dry years. Great profits have been made where

this has been possible. In future the storage of water in great reservoirs for irrigation purposes is sure to be an important element in solving the drought question.

I was in Brisbane at the hottest period of the year. Following the custom of the country, I wore lighter clothes, and less of them, and the heat seemed no greater to me than July weather in New York City though the records show the average heat to be somewhat greater. The Brisbane winter is so mild that we should hardly use that name for it. No effort is made to heat houses, or to build them for warmth. They are only to exclude the rain and wind, and consequently cost not more than half as much as corresponding houses in a cold climate. The savings in rents and in fuel which result from this are important elements in the ease and economy of life in Brisbane.

The railways of Queensland are owned by the government. For the resources of the country they seem hopelessly inadequate, although it is stated that there are more miles of railway in proportion to the population than in any other country in the world. There are 3114 miles of railway for a population of 528,000 or 5.86 miles per thousand of population. The gross receipts are 1,534,880 pounds sterling, or $7,460,000, equal to $14 per capita. The operating expenses are 56% of the receipts. The track is 3½ foot gauge, with durable hard wood ties, usually without other ballast than the natural soil. The curves are sharp, and grades up to 2% and over are very common. First and second-class passengers are carried on every train, apparently in about equal numbers, although no doubt statistics would show the second-class passengers to be more numerous.

The whole railway system is cheaply built and the trains are few and slow. They are few because business is light, and slow because the tracks would not stand a higher speed. Looking through the time-table the average speed of the longer runs does not exceed 25 miles per hour, although on the straighter stretches a running speed of 40 miles per hour is no doubt reached.

It must be remembered that, generally speaking, the railways only serve to connect the coast with the interior.

The coasting steamers are frequent, comfortable and cheap. They carry all the freight that is carried coastwise, that is to say, between the larger cities, which are all upon the coast, and they also get a large part of the passenger business. One can go from Brisbane to Sydney almost as quickly by water as by rail, and more comfortably.

The journey by rail is made from Brisbane to the frontier on the Queensland narrow-gauge road. The Queensland train draws up alongside the New South Wales train, which is standard gauge, and everybody changes cars. No freight is changed, for there is no through freight, the sea-route being so much better. Formerly there was a Custom House, and the old notices to passengers are still up, though interstate customs have been abolished for some years.

In New South Wales a Pullman sleeper is available. The train stops for all meals at eating-stations. The

meals are usually good and cost 50 or 60 cents. The entire journey of 725 miles (so long because parts of the road are very crooked) takes 28 hours, an average of 26 miles per hour.

Between Sydney and Melbourne there is also a change of gauge, and trains. The Victorian gauge is 5 feet 3 inches. The entire run of 582 miles is made in 17½ hours, an average of 33 miles per hour. On some unusually

good stretches I think with a little down grade to help, I timed spurts up to 50 miles per hour on the Victorian end of the line near Melbourne. The track is good, well ballasted and smooth riding.

Considering that Sydney and Melbourne each have about 600,000 inhabitants, and that this is the only railway line between them, and that in this case the land route is much more direct than the water route, the small amount of land travel between the cities is certainly surprising.

Up to 1890 Brisbane was supplied with water from two impounding reservoirs, holding together 1680 million U. S. gallons, and with a total tributary area of 16.77 square miles. The average rainfall is nearly 50 inches, and one

would suppose from northern experience that an ample supply of water could be obtained under these conditions. As a matter of fact, this old system is only good for about 2,400,000 U. S. gallons per day in a dry year. This is owing in part to the very irregular distribution of the rainfall throughout the year, and especially through a series of years, and in part to the very great amount of evaporation which greatly reduces the run off and further reduces the available volume of the water stored in the reservoirs.

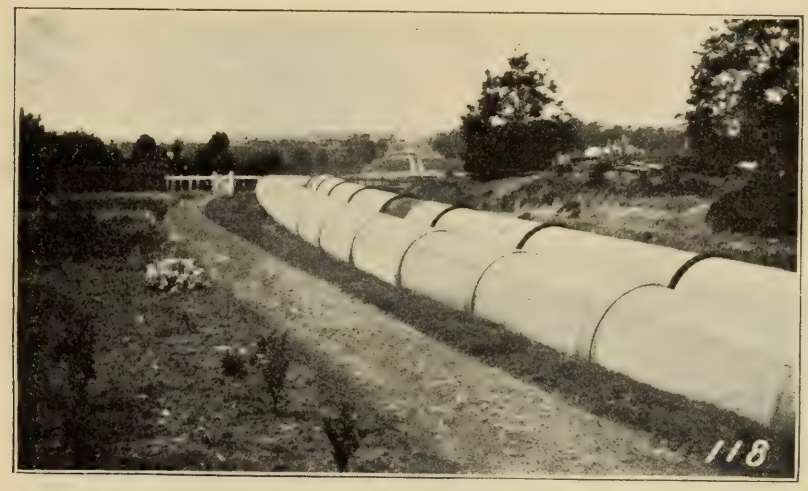
At the present time these older supplies remain in use and are most valuable as far as they go, but the water from them forms much the smaller part of the supply.

The reservoir waters are subject to growths of microscopical organisms which render the waters most unat-

tractive and objectionable. Copper sulphate has been applied to one of them, with fairly satisfactory results. The full correction of the difficulty is to be found in intermittent filtration something like that applied last year at Springfield, Mass.

The Brisbane Water Board has made extended experiments with this form of filtration, many of them dating back of the time when this method was taken up at Springfield.

When the old supplies became inadequate a larger supply was introduced from the Brisbane river, by pumping. A pipe-line 17 miles long was laid from the pumping station a short distance above the head of tide-water to the city. At the point of intake the river drains an area of 4000 square miles.



The average rainfall upon this area is about 40 inches. The amount of water flowing in the river in the aggregate is enormously greater than the requirements of the city, but its flow is extremely irregular. Enormous and destructive floods have occurred, but on the other hand, in the great and unequalled drought of 1902, it ceased to flow, and the supply of the city was only maintained by letting down water from the series of pools left in the bed of the river, by cutting channels through the natural dams which formed them.

The Brisbane river water is, generally speaking, rather clear and free from turbidity, but in floods it becomes very

turbid. The tests made by the Water Board show that sand filtration is incapable of clarifying it at such times. It can be clarified by mechanical filtration, following chemical treatment, and this method of purification is the most suitable one for treating it.

In order to maintain the supply through periods of drought, storage must be provided. Storage by damming the main stream has been proposed. But a reservoir formed on the main stream would be certain to become filled with gravel and silt deposited from the flood flows. This might not happen at once, because ordinary floods do not carry forward excessive quantities of suspended matter, but the larger floods, occurring at longer intervals, would certainly fill it to such an extent as to seriously reduce its usefulness.

Storage on a tributary of the main stream is clearly the most feasible solution of the difficulty. Fortunately there are excellent storage sites on a number of tributaries, and one of these has been selected for development.

The water from the reservoir to be built will be let down through the natural channels in times of drought, to maintain the supply. In any event such flow for a considerable number of miles in the natural channel will be

necessary, and this flow with the accompanying aeration is largely depended upon to remove tastes and odors from growths of organisms which must be expected in the reservoir waters.

In connection with these new river works, a new pumping station, pipes, etc., will be required and a purification plant is to be established to purify the river water and such reservoir water as is let down from the storage reservoir.

There are only a few small towns on the catchment area, and no sewage reaches the water courses. The total population is very small, and nearly all of it is scattered, in stations or farm houses. Cattle are far more numerous than human beings. They have access to the river and its tributaries, and are fond of standing in the waters. In the drought of 1902 many cattle died on the banks of the river, or in the water holes, giving rise, to most unpleasant conditions. Removing the bodies of such dead cattle was a difficult part of the Water Board's work at that time.

At the present time the public supply is used for drinking purposes to only a very limited extent. Drinking water is generally obtained from tanks filled from the roofs. The roofs are of galvanized corrugated iron. The tanks

are made of the same material. The water is soft but always contains a considerable proportion of zinc in solution. The zinc does not appear to be injurious to those who drink the water.

Only a few tanks are provided with appliances for wasting the first runoff from the dirty roofs at the beginning of a storm. Usually all goes to the tank, and considerable amounts of debris from it accumulates upon the bottoms of the tanks. I was furnished with various statistics upon this point which I will not quote. I will only say that the sparrows and pigeons on the roofs and in the gutters are often large contributors. A few people

put kerosene or "petrol" as they call it, in the tanks to prevent the growth of mosquitoes in the water. The dose to be effective must be repeated every time the tank overflows, that is to say, after every heavy rain. Screening the tanks is not generally practiced. In general the tanks are favorite breeding places for the mosquitoes, and they are worked to full capacity.

The tank water is colorless, and is easily distinguished from the public supply, which is somewhat yellow. It is also free from turbidity and from the iron resulting from putrefaction in the pipes, which is often troublesome in the public supply. It is further free from the tastes and odors

of organisms. On the other hand, it is flat and insipid in taste, though this is improved by the addition of a little salt.

Brisbane uses about 58 U. S. gallons of water per capita daily from the public works. The revenue amounts to more than $3.00 per capita annually and affords a fully adequate return on the capital invested in the works. When the new works are carried out the supply will be equal in quality to that of any city, and the quantity can certainly be maintained through any drought, and the revenue will serve to pay a fair return upon the present capital and upon the additional amounts that will be required.

STATISTICS REGARDING WATER SUPPLIES IN AUSTRALIAN CITIES.

	Melbourne.	Sydney	Brisbane.
Date of statistics,	1905	1905	1906
Population of district,	600,000	600,000	130,000
Population actually supplied,	511,900	561,715	100,000
Gross revenue,			
Pounds,	186,179	251,503	65,584
Dollars,	908,000	1,220,000	319,000
Dollars per capita,	1.75	2.17	3.19
Capital value:			
Pounds,	3,768,269	4,608,581	553,369
Dollars,	18,300,000	22,500,000	2,700,000
Dollars, per capita,	35.20	40.00	27.00
Operating expenses: (Exclusive of extensions)			
Pounds,	33,792	66,015	20,423
Dollars,	164,000	322,000	99,000
Dollars per capita,	0.32	0.57	0.99
Consumption,			
Imp. gals. per capita,	63.4	38.65	48
U. S. gals, per capita,	76.	46.	58
Millions of imperial gals.,	32.4	21.7	4.8

SOME NOTES ON ORIENTAL WATER WORKS.

By George A. Johnson.

During the writer's recent trip around the World it was his privilege to make a somewhat extended study of numerous Oriental water works. It would be out of place in a paper of this character to go much into detail or to attempt a complete description of all the works visited. In this article, therefore, will be given as briefly as possible the more salient features of Japanese waterworks, and of the works at Shanghai, China, Singapore, Straits Settlements and Bethmangala and Calcutta, India, observing the general lines followed by the writer in his illustrated lecture on this subject delivered last June at the Toronto Convention of this Association.

Some of the data used in this paper have been taken from an article by the writer which appeared in the Engineering Record, May, 11, 1907. For their great kindness in aiding the writer in his endeavor to obtain information upon the works described, hearty acknowledgments are due to Dr. Y. Nakajima of Tokyo; Mr. S. Inoue and Dr. S. Tanabe of Kyoto, Mr. Z. Mita of Yokohama; Mr. K. Funabiki, Mr. H. Ono, Mr. K. Inouye and Mr. Y. Tsujimura of Osaka, Japan; Mr. McLeod and Mr. Mollison of Shanghai, China; Mr. Pierce of Singapore and Mr. Bell of Penang, Straits Settlements; Mr. Fogarth of Bethmenagala and Mr. McCabe and Mr. Pierce of Calcutta, India.

THE WATER WORKS OF JAPAN.

There have been public water supplies of a kind in Japan since the year 1600 when Iyeyasu, founder of the Tokugawa dynasty of Shoguns, inaugurated the first public water supply at Tokyo. These original works were remodelled and improved some 65 years later, and were improved and extended many times during the next two centuries. It was not until 1892, however, that the present modern and efficient works were put under construction, and it was 1898 before they were completed.

To Yokohama* belongs the credit for having installed the first modern system of water works in Japan. Construction of these works was begun in 1885. In 1889 the construction of the Nagasaki water works was begun.

Osaka commenced her works in 1892, Hiroshima in 1896, Kobe in 1897, Hakodate in 1898, Shimonoseki and Okayama in 1900 and Akita in 1903. In all, therefore, there are ten cities in Japan provided with public water supplies nine of which are filtered before delivery to the consumers, the Hakodate supply being unfiltered. In addition to these ten cities there are Kamiura, Sawarazawa and Iizuka, towns with populations of 2,165, 1,396 and 1,240, respectively, which have public supplies, that of one, Kamiura, being filtered.

The total population of the thirteen cities and towns which have public water supplies is in round numbers about 4,100,000, and of this number roughly 4,000,000 are supplied with filtered water. In general terms about one-third of all service lines are metered, and there is a fire hydrant provided to about every 50 houses. The average daily water consumption is about 25 gallons per capita. The total capital cost of all existing Japanese waterworks systems to date is in round numbers $11,500,000, or $2.80 per capita.

THE TOKYO WATER WORKS.

The original design of these works called for a capacity of 45,000,000 gallons per day, or sufficient to serve a population of 1,500,000. Construction work was begun in 1892 and the works were first put into commission in 1898. In 1904 the population of Tokyo was 1,870,628.

The intake is located on the Tama River at Hamura, and from there to the present works the water flows by gravity through about 30 miles of open and closed canal. On reaching the works at Yodobashi the water passes

* For the data from which the following digest of modern water works practice in Japan has been prepared the writer is indebted to his friend, Mr. S. Inoue, chief engineer of Kyoto Municipality, Japan, and a member of this Association.

through sedimentation basins, three in number, each 720 x 360 x 19.5 ft. deep, having a total capacity of 67,300,000 gallons. These basins may be worked intermittently or continuously and when operating as continuous flow basins the period of sedimentation is equal to about 36 hours, and the velocity of flow through them to about 0.067 inch per second.

From the sedimentation reservoirs the clarified water flows through regulated outlets onto slow sand filters of which there are eighteen one acre units. The sand layers are 30 inches in depth and are supported by 24 inches of graded underdraining material. The filters are operated at a rate of 2,933,000 gallons per acre daily, corresponding to a total gross capacity for the 18 filters of 52,794,000 gallons daily.

The filters require scraping about seven times a year on an average. At such times the dirty sand is removed from the beds, dumped into cement lined troughs, water applied and the sand agitated by coolies with rakes until clean.

There are three filtered water basins, all covered, located at Yodobashi, Hongo and Shiba respectively. The capacity of each basin is 7,500,000 gallons, corresponding to a total storage capacity of about 12 hours.

Two thirds of the supply is delivered by gravity to the low level districts. The remaining one-third is pumped at the Yodobashi station to the high level districts in Yotsuya, Akasaka, Azabu, Shiba, Kojima, Ushigome, Koishikawa, Hongo and Kanda wards. The pumping station at Yodobashi contains four 300 H. P. pumping units, each of a capacity of 7,500,000 gallons per day when working against a head of from 80 to 100 feet. There are twelve Lancashire boilers and two sets of Green economizers.

The charges for water vary, according to the use to which it is put, from 6 cents to 10 cents per 1,000 gallons. The water is of excellent quality, clear, soft and without noticeable color.

At the present time there are 85,539 services and 5,177 fire hydrants. The metered services number 20,514.

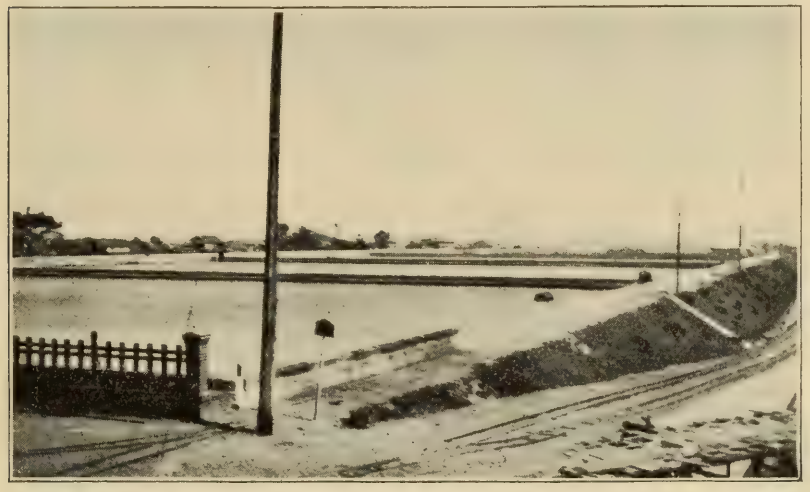
The water consumption ranges from 11 to 23 and

averages 17 gallons per capita daily. The total cost of the works to date is $4,250,000.

THE OSAKA WATER WORKS.

The Osaka water works were put under construction in 1892, and originally designed to serve a population of 600,000. They were later extended to serve a population of 800,000. The population of Osaka in 1904 was 1,026,767.

The supply is derived from the Yodo River from whence it is raised by three centrifugal pumps to a series of four settling basins against a total head of about 30 feet. After 36 hours sedimentation the water is applied



to slow sand filters and then pumped by seven tripple expansion pumping engines of the Worthington type to the distributing reservoir at Osaka Castle against a total head of about 130 feet. The capacity of this storage reservoir is 3,750,000 gallons.

The raw river water has a turbidity ranging from 10 to 350 parts per million. There will be about 20 days in the average year when the turbidity of the raw water will be over 100 parts per million, and about 50 days when it will be over 50 parts. The alkalinity averages about 20 parts per million, and the numbers of bacteria range from 40 to 30,000 and average about 2,000 per cubic centimeter.

The settling reservoirs, four in number, are each 330 x 360 x 12 feet. effective depth. Their combined effective capacity is 42,600,000 gallons. The sediment in these basins is flushed out once annually, when between 3 and 4

inches, or about 5,200 cubic yards are removed. The cost of labor for flushing out this material is 2 cents per cubic yard.

The cost of the basin completed in 1903, the effective capacity of which is about 10,000,000 gallons, was $83,370, exclusive of the cost of land which costs at present $2.00 per tsubo, or $2,420 per acre.

The filters are of the slow sand type, eleven in number, ten of which are 151 x 182 feet and one 182 x 350 feet. The total filtering area is therefore 7.77 acres. The tanks are of concrete and brick and the filter finished in 1903, 182

x 350 x 7.5 feet deep cost $40,700 or $27,840 per acre exclusive of the filtering material which cost about $3,000 per acre additional.

The filters are operated in an up to date manner, although the rate of filtration is not automatically controlled and fluctuates with the pumpage. The average actual rate of filtration is 2,900,000 gallons per acre daily. The net rate is equal to about 2,600,000 gallons per acre daily.

Each filter requires scraping about twice a month on an average, and at such times about one-third inch of material is removed. No attempt is made to recover by washing the sand thus removed and it is used for fill. A gang of coolies is kept busily engaged at the river bank practically all of the time screening sand which is hand dredged from

the bed of the Yodo River opposite the water works, brought to the shore in boats and there sun dried and pan screened.

The water rates vary from 10 to 60 cents and average about 20 cents per 1,000 gallons. The filtered water is of excellent quality, has an alkalinity of about 20 parts per million, and during the year 1905 contained the average number of 25 bacteria per cubic centimeter.

There are at present 48,513 services of which 9,369 are metered. There are 3,000 fire hydrants. The total cost of the system to date is $1,653,020.

THE YOKOHAMA WATER WORKS.

The Yokohama water works were put under construction about 22 years ago when the first pipe lines were laid from the Sagami River. The new intake is located on the Doshi River near the foot of Fujiyama, and from there to the site of the filtration works on Nogiyama, a distance of some 30 miles, the water flows by gravity.

The works were originally designed to serve a population of 70,000 and have since been extended to serve 300,000 people. In 1904 the population of Yokohama was 331,597.

The raw water of the Doshi River is normally clear and noticeably free from color and turbidity except at times following heavy rains. The alkalinity of the water is about 27 parts per million.

On reaching the filtration works the four supply mains discharge into two receiving wells of masonry construction and from them the water is distributed to slow sand filters. These wells are small and permit of comparatively no storage. Suitable regulating devices are provided to maintain a constant water level in the wells and on the filters.

The three slow sand filters built some 21 years ago have recently been supplemented by three more filters. The beds are arranged in two batteries, one of four and one of two filters. The former are each 120 x 70 feet and the latter are each 120 x 80 feet, corresponding to a total filtering area of 1.212 acres. The tanks are built of masonry and brick. The sand layer is 2.5 feet thick supported on a

layer of graded underdraining material 18 inches in depth. The sand is of medium size, rather dark in color, and of good stable quality. It costs about $2.75 per cubic yard in the filters.

The filters are operated at the somewhat high rate of 6,530,000 gallons per acre daily, and require scraping about about once a month. Sand Washing procedures are similar to those employed at the Tokyo water works.

There are two baffled clear water basins, both covered and having a total capacity of 3,192,000 gallons, corresponding to a storage of practically 12 hours supply.

The filtered water is high grade, clear, soft and colorless, and stands in enviable repute among the citizens of Yokohama. The works are well built and well operated. There are at present 2,745 metered and 7,679 unmetered services. There are 1,236 fire hydrants, or one to every 50 houses. The consumption ranges from 19 to 29 and averages 24 gallons per capita daily. The total cost of the system to date is $1,548,140.

THE KOBE WATER WORKS.

The Kobe water works were put under construction in 1897 and consist of impounding reservoirs in the hills immediately back of the city, slow sand filters, and small distributing reservoirs. The system is a gravity one throughout.

The impounding reservoirs, two in number have a total capacity of 483,000,000 corresponding to a storage

of 140 days supply at the average rate of consumption of 3,480,000 gallons daily.

The catchment area for the most part consist of the steep slopes of the hills back of the city and two small brooks serve as the main feeders. The watershed is but sparsely populated owing to its mountainous character.

The raw water, owing to the lengthy period of storage allowed, is never excessively muddy when applied to the filters. It is soft and free from noticeable amounts of color.

The filters are eleven in number, and have a total area of 3.04 acres. Prior to its application to the filters the water passes through a small settling reservoir of a capacity of 1,000,000 gallons. The distributing basins are 5 in number and have a total capacity of 260,000 gallons.

There are at the present time 11,581 services in the city, 2,576 of which are metered. There are 1,173 fire hydrants. The works were designed to serve a population of 250,000. In 1904 the population of Kobe was 295,276.

The water consumption ranges from 20 to 40 and averages 30 gallons per capita daily. The total cost of the system to date is $1,468,640.

THE NAGASAKI WATER WORKS.

These works were put under construction in 1889, and consist of impounding reservoirs, slow sand filters and distributing reservoirs. It is a gravity system throughout.

The original works were designed to serve a population of 60,000, but have since been extended to serve 182,000. In 1904 the population of Nagasaki was 159,041.

The impounding reservoirs are three in number and have a total storage capacity at a daily average consumption of 1,680,000 gallons of 293 days' supply, or 493,000,000 gallons. The supply is drawn from small mountain streams.

From the storage reservoirs the water flows to the slow sand filters, nine in number and having a total area of 2.36 acres. From the filters the water flows to four clear water basins, having a total capacity of 2,930,000 gallons, from which it is distributed by gravity to the city.

At the present time there are 5,901 services in the city, 953 of which are metered. There are 492 fire hydrants.

The total cost of the system to date is $788,080.

THE WATER WORKS OF HIROSHIMA, SHIMONOSEKI, AKITA, HAKODATE, IIZUKA AND KAMIURA.

The following notes will serve to give the main features of the water works of the above named cities and towns.

HIROSHIMA. Construction work was begun in 1896. Population in 1904 was 127,117. The works were designed to serve a population of 120,000. The source of water supply is the Ota River. There are two settling basins with a total capacity of 1,200,000 gallons. The slow sand filters, four in number, have a total area of 1.75 acres. The clear water basins, two in number, have a total capacity of 950,000 gallons. Water consumption ranges from 15 to 40 and averages 28 gallons per capita. There are at present 6693 services in the city, 1610 of which are metered. There are 709 fire hydrants. The total cost of the system to date is $465,560.

SHIMONOSEKI. Construction work was begun in 1900. Population in 1904 was 46,905. The works were designed to serve a population of 60,000. The supply is derived from small mountain streams. The impounding reservoir has a capacity of 286,000,000 gallons. There are three

slow sand filters with a total area .87 acre. There are two clear water basins with a total capacity of 270,000 gallons. Distribution is by gravity. Total cost of the works to date is $449,080.

OKAYAMA. Construction work was begun in 1900. Population in 1904 was 81,324. The works were designed to serve a population of 80,000. The source of supply is the Asahi River. There are two settling basins with a total capacity of 3,090,000 gallons. There are four slow sand filters with a total area of 1.31 acres. There are two clear water basins with a total capacity of 810,000 gallons. The total cost of the system to date is $401,900.

AKITA. Construction work was begun in 1903. The population in 1904 was 33,695. The works were designed to serve a population of 40,000. The source of supply is drawn from the Asahi River, a branch of the Omono River. The settling basin has a capacity of 1,090,000 gallons. There are two slow sand filters with a total area of .66 acre. The capacity of the clear water basin is 750,000 gallons. The total cost of the system to date is $235,150.

HAKODATE. Construction work was begun in 1898. Population in 1904 was 88,071. The works were originally designed to serve a population of 60,000, but have since been extended to serve a population of 150,000. The supply is drawn from the Aka River. The storage reservoir has a capacity of 1,530,000 gallons. The water is not filtered. There are two distributing reservoirs, the total capacity of which is 1,920,000 gallons. The daily water consumption ranges from 22 to 35 and averages 26 gallons per capita. There are at present 2,509 services in the city, 729 of which are metered. There are 410 fire hydrants. The total cost of the works to date is $229,310.

SAWARAZAWA. Construction work was begun in 1898. Population in 1904, was 1,396. The works were designed to serve a population of 1,229. The supply is drawn from small mountain streams. The impounding reservoir has a capacity of 300,000 gallons. The water is distributed by gravity direct from this reservoir to the consumers. The total cost of the works to date is $5,060.

IIZUKA. Construction work was begun in 1898. Population in 1904 was 1,240. The works were designed to serve a population of 1,085. The supply is drawn from mountain streams. The impounding reservoir, from which the water is distributed direct by gravity to the consumers, has a capacity of 200,000 gallons. The total cost of the the works to date is $3,410.

KAMIURA. Construction work was begun in 1900. Population in 1904 was 2,165. The works were designed to serve a population of 2,500. The source of water supply is the Ushimaki River. The water is applied direct to a small sand filter (area .017 acre). The clear water basin has a capacity of 22,000 gallons. The total cost of the works to date is $3,410.

THE WATER WORKS OF SHANGHAI, CHINA.

Shanghai is located on the east coast of China, south of the Yellow Sea and near the mouth of the Yang-tse-Kiang. It has a population of about 600,000. The water works were built with the particular object in view of sup-

plying the foreign population of that City with pure water. The total number of people tributary to these works at present is in round numbers 45,000, of which about 12,-

000 are of English and American birth and the remainder Chinese.

The water supply is drawn from the Hwang-ho River, the waters of which are normally very turbid as is the case with all rivers emptying into the Yellow Sea. In fact it is the excessive muddiness of such waters as those of the Yang-tse-Kiang and Hwang-ho that gives the name to the Yellow Sea, the waters of which are colored a deep yellow for more than a hundred miles from the mainland of China.

The raw water is raised from the river by two centri-

fugal pumps of local make and discharged through two 20-inch pipes into the settling basins. These basins are four in number and provide a period of sedimentation of about 25 hours.

From the settling basins the water is applied to slow sand filters of which there are twelve. The areas of these beds range from 1/6 to 1/3 acre. Considerable fine clay remains in suspension even after a preliminary sedimentation of 25 hours, and the filters require scraping at intervals of one month or less.

Passing the filters the water flows to a clear water reservoir having a capacity of 6,000,000 gallons, and is

pumped therefrom through one 25-inch and two 20-inch mains to the consumers. The daily pumpage ranges from 5,000,000 to 7,000,000 gallons.

The construction work in this plant is high grade, and the filters are very efficient notwithstanding the fact that they are somewhat overworked at times.

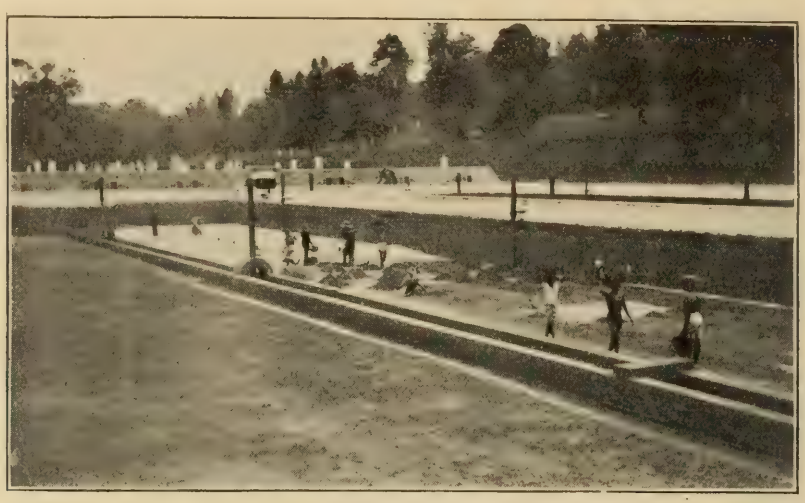
THE SINGAPORE WATER WORKS.

Singapore is located on the Island of Singapore at the southern extremity of the Malay Peninsular. The island is about 250 square miles in extent and is separated from the mainland by the narrow Strait of Tebrau. The population of the city is estimated at 200,000.

The water supply is derived from small Jungle streams which drain about 28 square miles. The storage reservoir is located on Thomson Road a short distance outside the city and has a capacity of about 1,000,000,000 gallons. The raw water is not particularly turbid but is always highly colored. Much of the time the water has a strong fishy odor and the taste is often highly objectionable.

The raw water flows from the storage reservoir by gravity to the outskirts of the city where the filtration works are located. The filters are of the slow sand type, eight in number, with a total filtering area of 2 acres. Operation is intermittent, that is, the beds are allowed to rest empty about 12 hours in every one to two weeks, the length of the operating period varying according to the

season. By this procedure it is understood that a considerable degree of success has been achieved in removing the objectionable tastes and odors from the water, although at the time of the writer's visit, July, 1906, the filtered water had a pronounced "fishy" odor. The actual rate



of filtration is said to be about 1,050,000 gallons per acre in 24 hours, corresponding to a daily yield of about 2,100,000 gallons for the eight filters. The average daily consumption is said to be about 5,000,000 gallons.

THE WATER WORKS AT BETHMANGALA, INDIA.

These works were constructed in 1903-4 for the purpose of supplying the Kolar Gold Fields with pure water. The gold fields are located in the State of Mysore, in southern India, and about 60 miles from Bangalore. The water works are located just outside the village of Bethmangala and about 7 miles from the gold fields. Up to the time of installing the present works the water supplied to the laborers at the mines was not only of extremely poor quality, but very scarce, a small given amount being allowed each laborer daily. These laborers are chiefly natives, but there are also, it is understood, some 800 English miners among the 20,000 workers at the mines.

The water supply is derived from the Palar River upon which the large storage reservoir at Bethmangala, together with many similar reservoirs used chiefly for irrigation purposes, is located. The capacity of this res-

ervoir is 1,737, 612,000 gallons, sufficient at a daily consumption of 2,400,000 gallons for 724 days supply. The rainfall at Bethmangala averages only about 17 inches annually and the raw water is deeply colored and at times is high in suspended matter.

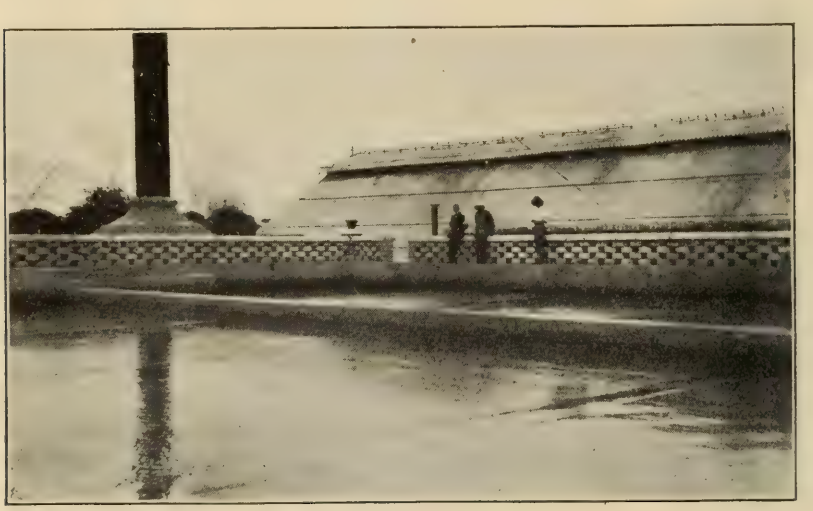
As to the filtration and distributing system, *the raw water enters a masonry inlet chamber located in the Bethmangala reservoir and thence flows by gravity to a suction well adjacent to the filter building from which it is raised

by two low lift pumps to the coagulating basin. The coagulant (sulphate of alumina) feed enters the raw water pipe leading from the low lift pumps to the coagulating basin. After four hours continuous coagulation and subsidence the water passes over outlet weirs into the supply pipe leading to filters of the American type. Passing the filters it is discharged through Weston automatic controllers into a flume and thence into the clear water basin, being raised thence by high lift pumps through a 16-inch main to the Kolar Gold Field against a total head of about 500 feet.

* A number of the details which follow have been taken from an article by the designer of these works, Mr. E. B. Weston, and published in the Engineering Record, December. 17, 1904, acknowledgment of which is hereby made.

The coagulating basin, located just outside the filter building, is uncovered, is constructed of granite masonry and lined inside with brick laid in "surki," mortar. The floor of the basin is of concrete. The basin is divided into two sections by a partition wall and has a capacity of about 400,000 gallons.

The filters, four in number, are of the Jewell gravity type, circular in plan and built of granite masonry. Over the manifold collecting system is placed a thin layer of gravel surmounted by 3.5 feet of fine sand. Each filter



has a rated capacity of 620,000 gallons, corresponding to a total capacity for the four filters of 2,480,000 gallons per 24 hours. The rate of filtration is automatically controlled by means of Weston effluent controllers.

The clear water basin is located about 30 feet from the filter building, is below ground level and covered. The basin is built of granite masonry and the roof of masonry.

There are two low lift pumping outfits with a total capacity of 5,280,000 gallons per 24 hours, and three high lift outfits of the Worthington type of a total capacity of 3,600,000 gallons per 24 hours. There is also a centrifugal pump for washing the filters having a capacity of 2,000 gallons per minute. The last named is belt driven by a Pelton wheel operated with water from the 16-inch high pressure main. Steam to drive the high and low lift

pumps is supplied by two Babcock & Wilcox boilers each of 225 H. P. with Green economizers.

There is a stand tank at Champion Reefs Mine in the gold fields, built of brick laid in cement mortar. All the filtered water is pumped to this tank from which lead branch lines to similar tanks located at the different mines, and to the service reservoir at Robertsonpet, a town about a mile distant.

The works were designed by Mr. Edmund B. Weston and built by the Jewell Export Filter Company, for whom Mr. R. W. Lawton acted as Superintendent of Construction. The amount of money appropriated for the work was $324,000.

Since the works were completed periodic analyses of

the raw water and filtered water have been made by the official bacteriologist of the Mysore Government. The average results of the test made during the period September 8-11, 1906, the last results available to the writer at this time, showed 4,350 bacteria per cubic centimeter in the raw water and 13 in the filtered water. Cholera, which prior to the installation of these works was very prevalent, has been practically absent among the employees of the mines since the works were put into operation. The filter plant itself is a model of neatness, and is operated in the most intelligent, painstaking and efficient manner.

THE CALCUTTA WATER WORKS.

Calcutta is located in the Province of Bengal, on the right bank of the Hugli River and about 45 miles inland from the Bay of Bengal. The present population is estimated at 1,100,000.

The Hugli River, from which Calcutta derives its water supply, is the most western branch of the Ganges. The drainage area of the Hugli is about 25,000 square miles, although in addition to the run-off of this watershed considerable excess flow from the Ganges enters the Hugli during July, August and September, when the flood season is at its height, through the Bhagirathi, Jellinghi and Matabanga Rivers which connect the Ganges and the Hugli above Palta.

The waters of the Hugli River are normally very muddy and at times, especially in the rainy season, excessively so. A better idea of the effect on the muddiness of the water produced by the heavy rains which occur in the rainy season may be had from the statement that while the average rainfall in this vicinity amounts to only about 60 inches annually, as much as 40 inches has fallen in a single week, and in 1900 the rainfall on two successive days was 14.5 and 10.8 inches.

The river water at the intake at Palta is subject to tidal influences: in fact the rise of the tides is felt 75 miles above this point. During the dry season, namely, February to June, the water is quite brackish for a part of practically every day necessitating a cessation in pumping for substantially one-half of the time.

The original works were put under construction in 1867, greatly enlarged in 1888, and now consist of two pumping stations where the water is raised from the river, settling reservoirs, slow sand filters, and gravity conduits to a reservoir on the outskirts of the city. Auxiliary pumps here force the water through mains direct to the

consumers in the northern part of the city, the remainder being discharged into three reservoirs, two situated in the town and one in the suburbs, from each of which it is again pumped to the remainder of the consumers.

The original settling basins, construction of which was begun in 1867, are six in number, and are built of masonry. Four are provided with semi-concentric silt-catching pits and two are plain. The original basins are each 500 x 250 feet, and range in depth from 7 to 9 feet. The total capacity of these six basins is 21,000,000 gallons.

The "new" settling basins finished about 15 years ago,

are merely earth excavations, puddling being practically dispensed with. Notwithstanding the fact that these basins are excavated in a sandy clay the leakage amounts to practically nothing. Two of these basins are each 2,500 x 350 x 9 feet deep. The remaining two basins are each 2,500 x 250 x 9 feet deep. The total capacity of the four basins is therefore 84,000,000 gallons, making a total capacity for the six original and four new basins of 105,000,000 gallons. These basins are worked on the fill and draw plan and the period of sedimentation is therefore variable.

As the water enters the settling basins it is treated for approximately three months in the year, namely, during the rainy season of July, August and September, with aluminoferric. The chemical is applied in the proportion of about 2 grains per gallon, although the method of application precludes accurate measurement. A bag of chem-

ical is suspended directly over the inlet, and is dissolved by the inflowing water. The aluminoferric costs about $20.50 per ton delivered at the works.

The original filters are twelve in number, each 100 x 200 feet corresponding to a total filtering area of about 5.51 acres. The filtering material consist of 30 inches of fine river sand supported on 4 inches of course sand and 12 inches of graded gravel, respectively. The effluent collectors consist of small cross drains covered with tiles. These drains lead the effluent to main collectors laid along the center of the beds and these main drains deliver the effluent into collecting wells from which it flows directly into the conduits leading to the auxiliary pumping station on the outskirts of the city.

The new filters are twenty-four in number, each 200 x 100 feet, corresponding to a total area of 11.02 acres. In construction these filters are in general the same as in the case of the original filters, with the exception that the effluent collectors consist of two courses of dry bricks laid sufficiently far apart to provide suitable waterways. The total filtering area of the thirty-six filters is 16.53 acres.

The average daily water consumption is estimated at 27,000,000 gallons daily (25 gallons per capita) and the actual rate of filtration at about 2,825,000 gallons per acre in 24 hours.

There are three effluent collecting wells in the plant, with a total capacity of about 42,000 gallons, and from these wells the filtered water flows through two conduits to the outskirts of the city. These conduits are 4 and 3.5 feet in diameter, respectively, and 12.5 miles long.

It is the custom at present to supply filtered water to the entire city, under about 30 pounds pressure at the various distributing stations during the day hours, excepting the hours 10 A. M. to 3 P. M., during which hours water is supplied under low pressure only to the more thickly populated sections of the City.

Filtered water is not used for street sprinkling, sewer flushing of fire extinguishing purposes, a complete separate unfiltered water system, being in use for this purpose, the water being pumped direct from the river into the raw water mains.

NOTE AS TO THE ACTION OF WATER UPON LEAD AND ZINC.

Dr. W. P. Mason.

Reports recording that a water contains so many parts per million of lead, zinc or other metal are common enough, but it is rare to find advance statements of what a water is capable of doing in the way of dissolving metals should opportunity be afforded it of coming in contact with it. In other words, a client who possesses a water supply which is very desirable at its source is seldom informed of the possible damage which may result thereto by reason of its being conveyed through metallic piping.

After the pipes have been laid and the water admitted to them, record is made of the result as to metallic solvency, but little is found in the nature of a prophecy antidating the outlay of capital, which prophecy, had it been uttered in time, might have had material bearing upon the investment. Again, if, as occurs in a few instances, the client be told that the water under examination is capable of acting upon certain metals he is not given the information in such quantitative form as will enable him to make comparisons between it and other waters with reference to this property.

It is well known that all waters do not equally possess the power to attack metals and it is proper to ask that, granting such power to exist, how far is its exercise objectionable from a sanitary point of view, or, to state it differently, what amount of metallic salts in solution may be allowed with safety?

The interesting case is given of "A water from the tail-race of a gold and silver mill which showed the presence of 350 parts of lead, 51 parts of copper and 1666 parts of arsenic oxide per million of water. This water, which was supposed to have caused the death of a number of cattle, was so highly charged with arsenic that an ordinary drink for man or beast would contain sufficient to kill".

(Utah Agr. Expt. Sta. Bull. 81, p. 199,)

Such a special instance however does not come within the limits of the present inquiry.

Let us consider for a moment the question of "plumbism" or lead poisoning as it is ordinarily presented under the classification of a water-borne disease.

The Massachusetts State Board of Health enumerates the symptoms of lead poisoning as some or all of the following: Anemia, constipation, indigestion, loss of appetite, thirst, metallic taste, abdominal pain, colic, "drop-wrist," blue line at margin of gums, lead in the urine.

Report of Mass. State Board Health, 1898, XXXIII.)

Dr. Hunter describing the effects of the epidemic at Pudsey, says: "Anaemia and debility were the most common symptoms. Patients nearly always complained that they felt as if they would sink down from weakness, and that the least exertion would make them sweat freely. The majority had the blue gum line so characteristic of lead poisoning. Colic was a common sympton. Paralysis was not common, but there were five or six cases of almost general paralysis and in these cases 'drop-wrist' was included. The amount of lead found in the waters producing these effects varied from .01 to 1 grain or more per imperial gallon. (.143 to 14.3 per million.)"

(Thresh. Examination of water page 88.)

There is some difference of opinion among the authorities as to the amounts of contained lead required to condemn a water, but all are agreed that even small quantities should be narrowly watched. Thus, the Massachusetts reports note that one-half part per million has caused serious injury. (Mass, State Board of Health 1898. XXXII.) Haines holds that .1 grain per U. S. gallon (1.71 per million) should cause a water to be rejected (J. Fk. Inst. Nov. 1890.)

Whitelegge believes that "No water should be used for drinking which contains more than one part of lead per million, and any trace, however minute, indicates danger." (Hygienc and Public Health.)

To quote Dr. Summerville in his recent paper in "WATER": "Lead to the extent of .25 part per million is sufficient to condemn a potable water."

That sundry waters contain enough lead to prevent their

acceptance by at least some of the standards above laid down is shown by the fact that a few years ago is was reported that sixty-three cities of Massachusetts possessed public water supply which contained lead in amounts varying from 85.46 to .032 per million. In four of these cities where lead poisoning was pronounced the average amount of the metal present during ordinary day time use was one part or over per million. Occasional instances of "plumbism" were noticed in other towns and doubtless mild or unrecognized cases occurred elsewhere. (Mass. State Board of Health, 1898, page 543.)

In the 31st annual report of the London local government Board (1901-02 Supplement on Lead Poisoning and Water Supply, vol. 2, page 426), peaty, moorland waters are shown to be especially plumbo-solvent, to a degree chiefly governed by the amount of acidity present, and experiments show that such acidity is due, at least in part, to acid-form bacteria residing in the peat.

For instance, the influence of acidity is shown by the action of the following moorland waters from Lancashire and Yorkshire:

(Thresh, Examination of Water, Page 186.)

Acidity of water in terms of $\frac{N}{01}$ C. C. of $Na_2 Co_3$ required to neutralize 100 C. C. of the water.	Milligrams ot Pb. in 100 C. C. of the water after filtering through Lead shot.
0.2	.28
.3	.25
.4	.4
.5	.66
.6	.92
.8	1.5
.9	2.4
1.1	3.2
2.2	8.6

The London report already quoted is so firm in its belief that the cause of plumbo-solvency has been located that it ventures to rate moorland waters as "safe" if they are neutral to lacmoid and as "dangerous" if they react

acid with that indicator. Attention is also called therein to the fact that moorland streams are highest in acidity during wet weather because of drainage from peaty surface sources and less so during periods of no rain on account of their supply at such seasons coming from the flow of springs.

In this connection it may be noted that H. W. Clark observed that carbonic acid in a soft water was the main factor that caused lead to be taken into solution by the waters from Massachusetts. (Engineering News, Dec. 1, 1904.)

It is by no means new to distinguish between the "solution" of lead and that "erosion" of the metal which some waters exercise whereby insoluble lead salts are formed which appreciably increase the turbidity of the water.

Such classification of the action upon lead has been developed by the report of the London Local Government Board with great care.

For our purposes it will suffice to note that "erosion" does not occur in the absence of oxygen, and we are also to remember that from the sanitarian's point of view "erosion" may be fully as objectionable as "solution" if no opportunity for clarification be furnished. In fact, the former may readily be the greater evil of the two, because of its involving the possibility of the ingestion of large quantities of lead salts held in suspension.

Piping water in tubes of galvanized iron is very common, and as zinc is often more easily attacked than lead it is pertinent to ask if it be equally dangerous. So far as our present experience can guide us towards a correct solution of this question, the reply must be a negative one and the following opinions are presented in support of such contention:

In the journal of the German Society of Gas and Water Engineers for 1887, H. Bante collected statistics to show "that the use of galvanized pipes should be in no way detrimental to health".

Similar views are entertained by V. Ehumann, director of the Water Supply of Wurtemburg. (J. Fk. Inst. Nov. 1890.)

According to Thresh (Examination of Waters and

Water Supplies, page 85.) "There is no doubt that waters containing traces of zinc are used continuously for long periods without causing any obvious ill effects. The water supply to a small hospital with which I was connected for some years always contained a trace of zinc, probably never more than half a grain of the carbonate per imperial gallon. (7.1 parts per million), but I never observed any indications of its being deleterious, although such effects were looked for."

In the Massachusetts Board of Health report for 1900, page 495, the following table is given showing amounts of zinc in sundry public supplies, the metal having been dissolved from pipes of galvanized iron or brass during ordinary use. The results are averages and are in parts per million:

West Berlin	18.46	Lowell	0.33
Milbury	3.08	Webster	0.28
Newton	1.25	Sheffield	8.65
Marblehead	0.85	Palmer	2.90
Grafton	0.73	Beverly	2.71
Wellesley	0.68	Fall River	0.07
Fairhaven	0.52		

The first of the above, West Berlin, drew its water through four thousand feet of galvanized iron pipes. The quantity of metal dissolved therefrom was certainly large but appears to have produced no evil results. "As far as is known the amount of zinc present in these waters as used is not sufficient to have any effect upon the health of the consumers of the water."

"The Board has investigated the question of the presence of zinc in drinking water supplies where galvanized iron pipes are used and, except in case of the use of some ground waters, containing very large amounts of free carbonic acid, which dissolves zinc and many other metals very freely, the amount of zinc found in ordinary water supplies, where galvanized pipes are used, is not sufficient, in the opinion of the Board to give anxiety." Massachusetts Board of Health, 1902, XLIII.)

In a private letter of more recent date the president of the above mentioned board says: "If there had been any harmful effects of the presence of zinc in the public drinking waters of the State that fact would have undoubtedly been brought to our attention. No statement to this effect has been made, nor has there seemed to this board reason for suspecting serious danger from this source."

As an instance of long continued use of a water containting much zinc, the case of Brisbane, Queensland should be quoted. In that city rainwater tanks built of galvanized iron are found in all the houses. The water, which is in common use, contains about 14.3 parts per million of zinc, yet no harmful effects have been observed.

(Hazen. Eng. News, April 4, 1907.)

In his experience the writer has been unable to trace any evil effects due to the presence of zinc in drinking water, even when the quantity rose as high as 23 parts per million in a water which is in constant use. It might be well to add, that in the particular case just cited the zinc was derived from a long stretch of galvanized iron pipes and the amount of the metal present was subject to great and frequent fluctuations for reasons that were not apparent.

It must be admitted however, that, even on the assumption that the presence of zinc in water is of no sanitary significance, its being there is nevertheless, not desirable, and the probability of a water being able to dissolve it should be determined and reported upon.

What can now be said with reference to some convenient and standard method of reporting the possible action of water upon any of the common metals?

The suggestion offered is this: Let the action, whether of solution or erosion, be stated in parts per million, and let it be that of one litre of water acting upon one square decimeter of bright metal for one hour at 15 degrees Centigrade.

The mode of procedure followed by the writer is to submerge a piece of bright sheet metal, one deci-meter square in two liters of water contained in a wide mouthed bottle. The water is occasionally given a gentle motion and is kept at 15 degrees for one hour, after which time the metal

in solution or suspension is determined. One hour is sufficient time to allow of the watching of metallic solvency, and let it be added, the limiting of the time of action to the standard period is important for the reason that the rate of action of the same water is not only variable, but the ratio of the total action during the different lengths of time is not a simple one. Thus, the quantity of metal attacked in ten hours is by no means ten times that acted upon during one hour.

In conclusion, let it be said that although we know in a general way that softness, acidity, dissolved gases and the presence of much chloride or nitrate will tend towards metallic action, while alkalinity and hardness are rated as protective agents, yet it is far better to actually test a water with reference to its behavior towards metals than to attempt any prophecy of its action based upon analytical knowledge of what the water may contain.

DISCUSSION.

MR. R. J. THOMAS: I would like to say a word which probably would be interesting in connection with Dr. Mason's paper, especially in regard to the wisdom of ascertaining before hand the action of any particular water on lead or zinc, and especially on lead. As the doctor says, there are not many well authenticated cases of zinc poisoning; but there seems to be no doubt that there is in fact such a thing as lead poisoning. In the city of Lowell in 1893, we put in a driven well plant at quite an expense to the city, that is as expenses go for driven well plants. We had been using that water for about three or four years when about forty cases of lead poisoning developed, which were traced to the satisfaction of the State Board of Health, to the water supply. The old theory was that as long as there was no noticeable action upon the lead pipe, that, of course, the water was not affecting the lead, and there was no danger of lead poisoning; but it was ascertained by the State Board of Health examination, as well as by Dr. Harrington, of the Harvard Medical School, whom we employed, that the quantity of lead to be found in samples of water run through lead pipes was, though we would consider it most infinitesimal—too small to be accounted for—still proved to be sufficient to cause lead poisoning, when taken day in and day out. I think the greatest amount of lead found in any of the samples of water taken was two tenths of a part in 100,000; but they claimed that even that was dangerous and sufficient to cause lead poisoning. It would have been a great expense to remove all the lead service pipes, so we put in another driven well plant, the water of which was examined before we accepted it as a supply and found, or pronounced by the State Board of Health of Massachusetts, to be safe in respect to its action on lead pipes. The property of the water that we found in the first well plant, which caused lead poisoning through its action on lead pipe, was an exsess of carbonic acid. This was not found in the other well water. We have been using the water of the latter wells since then, although we are occasionally obliged to draw upon the original or first well

plant, which according to Dr. Harrington and the State Board of Health, is absolutely safe to use for a short period, in an emergency, or say for a month or two; while its use constantly for a year or more was unsafe.

In view of that experience, and probably the experience of other places, it would be very wise and almost necessary for people putting in a water supply to examine into the properties of the water and learn how it will act upon lead or other metals injurious to the health of consumers. We found that this water that acted upon lead, also acted upon zinc and iron, and had some, though considerably less, effect upon tin.

NOTES ON WATER PURIFICATION AT ST. LOUIS.

W. F. Monfort.

The necessity of coagulation in purification of turbid waters of high color, such as occurs in many of our Western rivers, is generally recognized. It has been thought that the interest in the matter of coagulation and sedimentation as an essential part of any method of purifying such waters, whether in connection with or apart from filtration by slow sand or mechanical filters, will justify the presentation before this Association of a brief statement of chemical and bacterial results for the past year at one of the larger plants, treating daily an average of seventy million gallons of a water whose average turbidity is above 1200, color above 40 and where alkalinity is equivalent to 135 parts per million of calcium carbonate, using lime and iron sulphate as coagulants, without the use of filters.

Detailed description of the St. Louis plant has appeared in Engineering News, October 27, 1904, and a discussion of the method as then applied in Proceedings of the American Society of Civil Engineers LIV, D 236. The essentials may be briefly stated as follows:

The low service pumping station and coagulating plant are located in the extreme northern part of the City at a point on the Mississippi River, about five miles below the mouth of the Missouri. From the intake tower in the stream some 1,500 feet from shore the supply flows through a tunnel to a well or uptake shaft beneath the coagulant house, where it receives its charge of iron sulphate, thence through the inshore tunnel to the wet well. At this point it is freed from ice, when necessary, by bucket conveyors. From the wet well, the water with its charge of iron sulphate is lifted by the low service pumps to the distributing well, where the charge of milk of lime from the coagulant house is delivered by centrifugal pumps. It then flows by gravity to a series of six uncovered sedimentation basins, 670 x 400 x 14 feet (average depth), having a working capacity of about 24,000,000 gallons. The weirs between

successive basins are 610 feet long. A conduit runs on either side of the system of basins; allowing filling and drawing from any basin at will. In practice the end basins alone are used for filling. From the drawing conduit, the treated and settled water passes by a conduit seven miles long to the most southerly station at Bissell's Point, where are four smaller storage basins, and the clear well. From the latter as also from a basin connected with the conduit at an intermediate point three miles above, the high service pumps deliver the water to storage reservoirs and to the mains.

The raw water partakes very largely of the character of the Missouri River water, being ordinarily so much higher in turbidity than the Mississippi above the confluence of the rivers that the line of demarkation between the two waters is plainly noticeable. As showing the variable character of the water, Charts 1, 2, 3, are introduced, giving in graphic form the maxima, minima and average for each month of the past year of a few prominent characteristics.

Fluctuations in turbidity of 2000 or more parts per million occur in April, June, July, September and January; the difference between maxima and minima is less than 1000 in May, Novmber, December and March. The maximum turbidities for June and July were 3600, for September and January 2400, with a minimum of 120 for February. The year's average was 1248 p. p. m.

Fluctuations in suspended solids as determined by weighing are even greater than those of turbidity, being above 3000 for June, July and January, about 2000 for February and March and less than 1000 for four months, May, October, November and December. The maximum of the year falls in June; 5300 p. p. m., or almost 31.4 grains per gallon, while for January it was 3678 or 21.4 g. p. g. The year's minimum was 122 p. p. m. or 7 g. p. g. The monthly average follows generally the curves of maxima and minima. The year's average was 1205 parts per million or about 70 grains per gallon.

TABLE 1.

Variations in Raw Water. Parts Per Million.

TURBIDITY

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb,	Mar.
Max.	2100	1200	3600	3600	1800	2400	1500	900	500	2400	1500	1500
Min.	180	180	1050	1350	1200	900	500	400	275	400	120	700
Av.	1358	975	2856	2261	1456	1398	866	702	375	1019	481	1183

SUSPENDED SOLIDS.

Max.	1645	1078	5301	4577	1769	1633	1191	944	496	3678	2537	2380
Min.	394	122	842	1032	692	568	412	362	139	249	146	733
Av.	1096	691	3417	2182	1164	947	691	592	264	1110	661	1444

COLOR.

Max.	51	51	41	41	45	41	41	71	70	65	70	70
Min.	35	31	31	31	31	25	31	35	35	30	35	30
Av.	52	38	33	36	35	34	35	52	57	49	49	45

ALKALINITY

Max.	127	148	146	129	139	143	176	175	172	167	176	152
Min.	90	94	126	118	120	120	119	154	160	63	90	106
Av.	110	134	134	123	129	136	147	163	167	107	145	133

COEFFICIENT OF FINENESS.

Max.	.914	.141	1.606	1.272	.983	.907	1.007	1.203	1.102	2.415	2.024	1.602
Min.	.606	.559	.802	.765	.563	.555	.654	.603	.657	.83	.85	.966
Av.	.827	.708	1.17	.963	.80	.677	.798	.844	.836	1.33	1.37	1.22

How widely the character of the suspended matter varies, the second chart shows: from a minimum fineness of .555 in September to a maximum of 2.415 in January, with the year's average at .953, slightly less than the standard fineness. The peaks of June (1.6) and January (2.4) mark flood stage, with consequently coarser material transported.

The minimum alkalinity of the year 63 p. p m., occurs in January flood water, when the variation was more than 100 p. p. m. Otherwise the monthly variations lie with smaller limit of 10 to 80 p. p. m. The average for the other months runs from 107 to 167 parts per million. The color range is from 25 to 71 with a yearly average of 43.

Chart 4 shows two typical cases of fluctuation in character of the river water. The data is given in tables 2 and 3. From January 17th to 24th the river rose eleven and one-half feet with a corresponding rise in turbidity from 400 to 2500 parts per million, and a decline in alkalinity from 137 to a minimum (on the 23d) of 63 parts per million. The dissolved solids declined from 255 to 138, color fluctuated irregularly, but remained high throughout. This is typical of a seasonable flood. It was on January 19th that the coefficient of fineness reached 2.4.

TABLE 2.

1907	Gauge	Turbidity	Color	Alkalinity	Dissolved Solids
Jan. 17	85.8	400	45	137	255
18	88.4	600	60	120	220
19	90.3	1000	60	107	192
20	94.	1500	60	104	
21	96.7	1800	65	80	138
22	97.1	2400	55	65	141
23	97.3	2400	55	63	142
24	96.9	2100	45	68	155

TABLE 3.

1907	Gauge	Turbidity	Color	Alkalinity	Dissolved Solids
May 27	86.2	750	50	127	219
28	86.9	600	35	130	238
29	87.0	1500	50	130	221

The other case occurred in May, 1907 and is typical of the Missouri's habit of cutting a new channel suddenly. Accompanying a rise of one-tenth of a foot came an increase of turbidity from 600 to 1500 parts per million, while the dissolved solids, alkalinity and color waver slightly, but independently, of the turbidity. Cases less marked than this latter one have been of constant occurrence throughout the year, wherein the shifting of the channel of the Missouri or of the Mississippi just below their confluence, has caused similar wide and sudden fluctuations.

It has been already stated that in the St. Louis plant the removal of suspended matter is accomplished without appeal to filters. On passing to the first or filling basin in the series of six previously mentioned, the coagulated water from the distributing well carries its natural sediment and the added coagulum. Sedimentation is so rapid that before the first basin is traversed the water is very largely clarified. The turbidity is reduced to about 15 parts per million on leaving the first basin; most of the suspended matter is fairly coarse at the first weir, and drops out in passing the succeeding basins, so that at the third weir the turbidity approximates 12, at the fifth 10 or less. It will be understood that the suspended matter in the earlier basins is too coarse for accurate determination by optical methods. Direct weighing of the suspended matter show results which are tabulated with other data in Table 4.

TABLE. 4.

	River	Weir 1	Weir 2	Weir 3	Weir 4	Weir 5	Weir 6	Tap
Suspended Solids	1444.	14.2	12.1	8.35	7.1	5.8	5.46	2.56
Color	145.3	13.6	13.	13.	12	11.6	10.8	10.8
Alkalinity	133.	51.1	47.6	47.	46	45	44.5	41
Bacteria Per C. C. M.	57029	933.	.....	501	.....	106	.....	42

The figures given are monthly averages for March, 1907. The daily data for the same period varies but slightly from the averages. In the accompanying chart this data has been reduced to a percentage basis, save the color, which is plotted in parts per million. Accompanying a reduction of suspended matter to less than 2 per cent., the bacterial reduction through the basins goes with almost even progress. When it is remembered that a portion of the suspended matter carried over the weirs is adventitious, produced by the softening reaction, and not bacteria laden, as is the original river sediment, it will not be surprising that the sudden decline in the solids is accompanied by the removal of so large a percentage of bacteria. Most of the original sediment and the coagulum falls out in the first half of the first basin, leaving the deposit about the filling gates, several feet deep, while the later traversed half of the basin has but a few inches of deposit, after even four months use.

Basin No. 1 was put into commission January 8th and the March data plotted show results in the third month of use. It must be stated, however, that the sewer of the filling basin is opened daily without interrupting its use, to allow the lighter accumulated flock and sediment to flow out.

The March averages plotted in the chart are representative of the best working of the system and the best results attained. During the period January 8th—March 30th, the average removals were almost as satisfactory.

TABLE 5.

Average Bacterial removals, per cent.

	Basin 1.	3.	5.	Tap
Jan. 1907	93.7	96.	97.4	98.87
Feb.	95.9	98.4	99.0	98.8
Mar.	96.1	99.1	99.8	99.88

As typical of results through the year a period in March (4-11) has been selected for presentation showing the character and extent of changes in the raw water effected by treatment.

TABLE 6.

Comparison of Raw and Treated Water.

1907 Mar.	Suspended Solids		Color		Alkalinity		Calcium		Magnesium		Bicarb.	Bacteria Per C. C.		Per Cent. Removal	B. Coli.
	R	T	R	T	R	T	R	T	R	T	T	R	T		
4	1146	4.0	50	10	128	43	39.9	22.0	11.1	10.0	1	166000	80	99.94	.....
5	991	1.6	45	12	127	42	40.8	21.5	10.7	9.67	0	149000	70	99.99	.....
6	1103	1.6	45	10	132	43	40.9	19.3	11.1	10.7	3	95500	40	99.9	.....
7	1343	0.8	45	10	136	42	39.2	18.4	12.5	10.3	6	105100	20	99.99	.....
8	1087	4.8	45	12	132	43	40.0	18.8	15.	10.7	7	48750	50	99.9	.....
9	972	0.0	50	10	134	42	40.5	17.0	11.1	10.7	8	59000	40	99.9	.....
10	.....	.....	45	12	133	42	41.5	20.2	12.5	11.1	10	.....	.....	.....	.....
11	903	0.0	45	10	132	42	37.0	18.6	13.6	10.7	10	34800	60	99.8	.....

This data is graphically presented in Charts 6, 7 and 8.

Consideration of the last chart makes it evident that it is not necessary to carry caustic alkalinity through the basins to secure satisfactory bacterial removals. Not only was the tap water free from caustic, but in the period

under consideration,—March 4 to 11,—no caustic appeared in any samples on passing the weirs from basins 1, 3 and 5 save on the 9th and 11th. This conclusion is further supported by consideration of daily data for the entire month as also for the entire period, January-March.

It appears further that the removal of the colon bacillus is likewise not dependent upon the presence of free lime, or caustic alkalinity, through the basins, since tests for this bacillus were negative throughout the week under consideration and as well throughout the month.

AVERAGES FOR RAW AND TREATED WATER, March 4-11.

	RAW.		TREATED.	
Alkalinity	132	p. p. m.	42.	p. p. m.
Susp. Solids	1079	"	1.7	"
Color	46	"	10.7	"
Calcium	40	"	19.4	"
Magnesium	12.1	"	10.5	"
Bacteria	94000	per c. c. m.	50	per c. c. m.

The averages given for this period differ but slightly from the averages for the year, save in the extent of the removal of the magnesium, and in the actual numbers of bacteria per cubic centimeter, which are unusually low.

The raw and treated water at Bissell's Point (the Southerly high service station) for the year averaged as follows:

	River	Treated Water
Suspended Solids	1188	3.8
Color	43	10.7
Alkalinity	135	49.
Calcium	42.3	22.8
Magnesium	13.1	7.5

being a reduction of the Calcium to 54% and of magnesium to 57% of the original content of the raw water. In the river water there is approximately 0.05 p. p. m. dissolved iron; in the treated water 0.02 parts per million dissolved iron, while the total iron content of this water from the

clear well varies from 0.1 to 0.25 parts per million. Most of this is in the form of ferric hydroxide adherent to or absorbed by fine suspended siliceous matter and is in large part carried down with it in the after reactions, which are still incomplete in the clear well. The incrustants in the raw water are increased in the treatment by about 14 p. p. m. reckoned as calcium carbonate.

The color has not been reduced lower than an average of ten because the popular appreciation of colorless water has not yet developed beyond this point in the scale.

With reference to the matter of cost it may be said that the average has been:

Iron	2.13 g. p. g.	$1.442 per million gallon
Lime	7.39 "	2.454 " "
Chemical Cost		3.896 " "
Labor		.579
Power		.064
Improvements		.021
Repairs		.063
Total cost of treatment.		$4.623

The waste of water due to the daily flushing out of loose sediment from the filling basin, together with that used in flushing out the accumulated deposit when the basins are cleaned is approximately 2% of the amount pumped.

Some members of the Association may be interested in a method for continuous slacking of lime for water treatment which has been introduced at St. Louis during the past year as a result of an investigation carried on by the writer,—based upon the heat of hydration of lime, and the increase in efficiency of the milk of lime produced by hot slacking.

Prior to this year the method of slacking used at St. Louis since the installation of the plant was as follows: Cooling water from an auxiliary condenser was heated to 120° F., by live steam; and the water thus used for

slacking, giving a maximum temperature in the tanks of about 180°. During part of the past year a higher initial temperature (approximately 160° F.) was maintained for the hot water supply and a temperature of 200° or more in the slacking tank, since it appeared that using the same lime in like slacking tanks with only the difference in the initial temperature of the water, the efficiency of the effluent from a tank in which a temperature of 200° F., or more prevailed was 15% greater than when a temperature of 165-170° F. prevailed. In other words a serious loss in efficiency was caused by the low temperature of the water used. The accompanying table shows results of several series of comparative experiments, the same lot of lime being used throughout the experiments of each series.

Series	Tank	Initial Temperature of Water	Maximum Temperature of Suspension	Per Cent Efficiency
A.	1	110°	156	70.3
	1	120°	171.3	78.13
	4	122°	156	72.85
	3	172°	202	83.65
B.	4	127°	165	66.04
	3	165°	200	81.25
C.	4	117°	153.5	79.35
	3	172°	208	94.6

For several months a device has been in use which heats the hydrant water supplied for slacking by utilizing the heat developed in the slacking process.

The effluent milk of lime from the slacking tank flows through a circular steel tank. A coil of two inch copper pipe is submerged in this latter tank, the contents of which are agitated by paddles on a vertical shaft. The hydrant water passes through this coil to a head tank, its temperature being raised during the passage from 60 to 70° F., above the initial temperature of the cold water. From the head tank the hot water flows through adjustable orifices to the slacking tanks where a temperature of 200° F., or more

has been maintained by the heat of hydration; in a long series of observations; these are representative:

TEMPERATURE

Cold Water	Head Tank	Lime No. 1	Tank No. 2	Heater Tank
51	118	204	200	134
51	118	206	203	136
51	114	206	204	135

The apparatus has been successfully operated since February, and in a slightly modified form is incorporated in the plans of the new coagulating plant for which bids have been recently received. The suspension used are adapted to the individual tanks. Two of the slacking tanks now in use have short pipes carrying the effluent to the heater tank. These have their water supply adjusted so that the milk of lime has one pound of lime in 3½ lbs. of water. In two others having longer effluent pipes of six and eight feet respectively a suspension of 1 to 3¾ is maintained. Inasmuch as it is necessary to cool the milk of lime before it passes the centrifugal pumps, the amount of water needed for this purpose is actually reduced making the process economical from every point of view. The estimated saving over heating the water by live steam is nearly $3000 per year.

The residue left in the slacking tanks after sixteen hours continuous operation is reduced to less than 1%, where formerly 3% was a minimum. There is thus a further economy of time and labor in its removal.

A detailed discussion of the heat relation and chemical results will appear a little later when the results of a longer period are available.

DISCUSSION.

MR. BURDICK: I didn't quite understand what your time of sedimentation was. I understood it was something less than a day.

MR. MONTFORT: It is difficult to say how long the time of sedimentation is. When a change is made in the amount of coagulant the effect is shown within four hours in two of the basins, when the pumping is 3,600,000 gallons per hour. The working capacity of the basins is about 24,000,000 gallons each, or almost seven hours, pumping at the rate given above. It appears that a large proportion of the newly treated water passes directly over the weirs and over the larger body of water in the basins, with nothing like complete mixing or displacement. In less than ten to fourteen days, I have reason to think complete displacement of the water of the six basins is not effected.

MR. LEOPOLD: Do we understand that the results you show are secured with eight hours' sedimentation?

MR. MONTFORT: I should not want to say what was exactly the period of sedimentation, because part of the water passing the first weir has been in the first basin a few hours, and part has been there for a week, perhaps.

MR. LEOPOLD: What is the total capacity of your basins?

MR. MONTFORT: In the six basins there is a total of about 144,000,000 gallons, or say two days' supply.

MR. LEOPOLD: What change do you observe after two hours.

MR. MONTFORT: An increase in the charge of lime shows in the alkalinity of the water at the second weir after three to four hours; not that the entire body of water in two basins has been displaced, but part of the newly treated water has passed over the second weir.

MR. LEOPOLD: Do you not think that that is due to the small amount of the newly treated added lime water sliding over the surface of the reservoir to the weirs, and that that would not effect the displacement of the main body of water; in other words, you could not possibly get in two hours the bacterial reduction which you have ob-

tained; that is, if you secured a tank in which you could get an absolute displacement every two hours, you could not get the 96 per cent. bacterial reduction?

MR. MONFORT: In an ordinary baffled tank holding two hours' pumping, we should not probably get sufficient sedimentation to effect a 96 per cent. bacterial reduction.

MR. LEOPOLD: What is the highest number of bacteria you have had in the water?

MR. MONTFORT: In the raw water the highest number of bacteria per cubic centimeter was 166,000; in the treated water the number may run up to 1,500, or so.

MR. LEOPOLD: What has been the greatest degree of variation in the percentage you have got?

MR. MONTFORT: When we were using but four basins out of the six, while the clear well was cleaning and there was no sedimentation except in those four, the results dropped down.

This was in May, 1906. For this period the bacterial reductions from basin to basin are not available; since our observations on this point date from October. Perhaps the information you want is in some figures here, from the report of the City Bacteriologist: the average bacterial removals for the period 1905-1906 were 98.3 per cent.

MR. LEOPOLD: That is not what I want to know. I want to know what was the variation in those results; in other words, what was the highest number of bacteria remaining in the water and what was the lowest number, and what was the variation in percentage?

MR. MONTFORT: For what period?

MR. LEOPOLD: Any period at all.

MR. MONTFORT: During the month of March, 1907, the maximum number of bacteria per cubic centimeter was 80; the minimum (on two days) was 0; the percentage reduction was 99.7 to 100 per cent.

MR. LEOPOLD: Did you make any tests on the sedimentation basins at any other point than the weir in determining the flow or action, after changing your basins?

MR. MONTFORT: A long series of experiments with floats to determine the rate of flow through the basins was carried out a few years since, with results yielding little

information bearing upon the present situation. At that time the treated water was admitted to the first basin through a single gate, and very great variations in the rate of flow were found. During the period January-March, to which particular attention has been called, the treated water entered the filling basin by four gates on the north side—i. e., facing the first weir; the flow is further broken by aprons or shields in front of the gates, giving the entering water exit in lines parallel with the north wall and the first weir. No float experiments have been carried out to determine the rate of flow under the conditions now prevailing. Our conclusions regarding the time required to pass the sedimentation basins are based upon the results of chemical tests of samples from various points in the system.

MR. LEOPOLD: Did you take samples from any other parts of your basin to see whether the diffusion took place over the whole basin or not?

MR. MONFORT: We have taken samples from a number of points in the first basin, to assure ourselves of the fairness of the samples. It has been impossible thus far with the facilities at our command to make an exhaustive study of the rate of flow through the whole system.

WATER WORKS PLANTS AND THE PROPER RATES FOR DOMESTIC AND PUBLIC SERVICE.

John Ericson.

Several valuable papers on the subject of proper rates to be charged for water supplied to municipalities for domestic and public purposes have been presented to this association. The subject, however, is so important and interesting that the writer takes this opportunity of bringing this matter to the attention of the members of the Association more perhaps for the purpose of drawing out some additional discussion which later experiences might prompt than for the purpose of advancing any new ideas.

In former articles on this subject some writers have given much weight to the average rates in existence in a number of communities as a means of arriving at the rates that would be proper at any particular place. While such average rates may be of value when conditions as regards population, fuel, source of supply, method of operation, etc., are somewhat similar to the conditions at the particular city under consideration, such average rate should be considered only as a check on the results obtained by an independent analysis of all the conditions existing at the given place.

Where the law gives municipalities authority to fix the water rates to be charged by private companies operating under franchises, a misunderstanding of this whole question has often led to many unjust acts and continuous litigation.

Some outlying districts of the City of Chicago, having become parts of the city through annexation, are thus supplied with water by private companies. In some instances the City has bought the plants from the company; in others the water companies continue to exercise the privilege under the franchise right granted them before annexation. These private plants being operated on a small scale as compared with the larger

plants owned by the municipality and under quite different conditions of course cannot be run as economically per unit of service as the City plants.

The average councilman or legislator as well as the greater part of the water takers being unfamiliar with the various questions that enter into the proposition of fair water rates cannot understand why the citizens in one part of the city should have to pay any more for the supply of water than those on the other side of the street that forms the boundary line between the old part of the city and the annexed district. Without proper consideration of the differing conditions under which the service is rendered they are apt to urge and vote for water rates that are not only unfair but impossible from a financial point of view.

It is from the water works engineer in particular that information should be sought in order to properly adjust rates. This in many instances is not done but prevailing average rates in a few other places where the conditions may be quite different are obtained and serve as the basis for the rates to be established. The local conditions of water works plants vary from each other more or less in every instance. To make the rates at other places even where such rates are fair and proper in themselves the sole basis for the rates to be charged by any given company in any other place is, therefore, inadvisable and will often tend to unfairness and will often work an injustice to one side or the other.

The revenues obtained from the operation of a water works system are generally divided into:

First—Hydrant rentals.

Second—Water rates from private consumers.

Third—Revenues for public supply other than for fire purposes.

In most cases there is no income from the third item and the same must be included in either one or both of the first two items.

The total revenues must be sufficient to meet the following expenses:

First—Operating expenses. (In the operating expenses are included taxes, wages, ordinary repairs, fuel, oil, waste, etc.)

Second—Interest or dividends on capital actually invested.

Third—An annuity, which, placed at compound interest, will create a fund sufficient to repay the investment at the end of the contract or franchise period. In addition there may or may not be provided a small per centage of profit depending on the rate of interest figured.

$$\text{Total Revenue } R = \text{Operating Expense} + \frac{r\,C}{100} + \frac{a\,C}{1000}$$

or the net revenues $= \frac{r\,C}{100} + \frac{a\,C}{1000}$ in which r = rate of interest.

C = Capital = value of physical plant together with the business or accumulated going value, if any.

a = an annuity which at a certain rate of interest compounded will produce 1000 dollars at the end of the assumed life of the plant.

As the rates received during the first few years after building a new plant are usually too small to even pay operating expenses, a sufficient amount must be earned during later years to make up this deficiency and pay interest on the investment during this initial period. For the same reason the amount of the annuity must be computed so as to equal the investment when accumulated for a time several years less than the franchise or contract period. Anything less than a return of the capital invested with reasonable interest thereon means a loss to the investor.

In the case of new plants, C is easily determined, being an actual cost. In cases of older plants, different methods to determine the value are used by different engineers. Some hold that the first cost should even then be the basis for determining this value. This, however, is sometimes a difficult proposition, especially with plants that have had several of their parts worn

out or outgrown and replaced and where the records are incomplete.

A majority favor the reproduction method, or the determining the cost of reproducing the works as they stand, based on the value of labor and material at the time of the valuation. In either case, a proper allowance is made for depreciation. To the physical value thus determined is added the business or going value.

The business value of a water works system is now capable of logical and fairly exact determination. Data as regards operating expenses, as well as the revenues in the way of hydrant rentals, water taxes and so forth for a number of years are generally obtainable in detail. With the aid of such information, a forecast of the probable revenues, operating expenses, etc., for a few years in the future can generally be made, and experienced water works officials can fairly accurately determine such other factors that enter into the problem that cannot be definitely determined but are based on each man's individual judgment and experience.

The writer will not here enter into any further discussion of the methods now generally used in determining this business or going value of a water works system, as the subject has in a clear and able manner been treated by Mr. Benezette Williams, C. E., Chicago, in the matter of the appraisal of the water works of Dubuque, Iowa, in 1902, the entire proceedings in this case having been published. The same subject has also been touched upon by Mr. J. W. Alvord and Professor D. W. Mead in papers published in the proceedings of the American Water Works Association.

When the business value of a water works system has to be determined and added to the physical value for the purpose of fixing fair water rates, it may in some instance be improper to use the previous rates in determining this value, especially if the previous rates were excessive. In such cases proper judgment and adjustment are necessary, the existing local conditions being considered.

In the case of entirely new plants there is a period

of several years when the works must be operated at a financial loss, as it would not be tolerated by the consumers should charges for water be made to immediately cover all expenses. The rates as fixed in the beginning of the life of a water works system are, therefore, insufficient to meet the yearly expenses for some years, and it is proper to so figure the rates that the average receipts from the service will return a reasonable earning on the initial investment during the period of unprofitable operation.

After the works have been in operation a sufficient length of time a readjustment of the rates may be required and it is then that the method here outlined can be applied.

In the cases of private companies operating a system of water works, it seems to the writer that it is immaterial to the companies what the relative proportion of so-called hydrant rentals and revenues received from other sources may be except that the water company, of course, desires to have the hydrant rentals as large as possible in the first period of the life of the works.

The revenues must all come from the people of the city or community for which the works are being operated, and, while it is true that the hydrant rentals should be and generally are paid for out of general taxes, while the water taxes are paid by the consumers, where the entire population or nearly so are water takers, it does not materially affect the general result. A determination as to what proportion of the total income of the water company or department should be charged to the general fund and what proportion should be received in water taxes is, therefore in many cases more of a question between the citizens themselves than between the citizens and the water company.

The average citizen, however, when it comes to the question of water taxes, generally forgets that he is also a contributor to the general tax fund and it is, therefore, necessary to make such adjustments and divisions that the rates shall be fair and reasonable.

In order to arrive at the fair amount to be paid by

a municipality for what is called hydrant rentals, it is essential to know what proportion of the capacity of the system is required for domestic purposes and what is required for fire purposes. Hydrant rentals should include not only the interest on the cost, the repairs and maintenance of hydrants and the cost of the water used for fire purposes, but the interest as well on the additional capital required to construct a system that will meet the increased requirements, as well as the proportional part of the additional maintenance and repair charges to this enlarged system.

For a properly designed system the following method may serve as an illustration:

The average daily per capita consumption varies considerable in different places and has to be considered separately in each individual case. For a city with a liberal per centage of the taps metered, the ordinary daily average per capita consumption may, at least for the purpose of illustration, be determined by Coffin's formula.

$$q = 40X^{0.14}$$

Where q = ordinary daily average per capita consumption in gallons X = population in thousands.

Assuming the maximum ordinary consumption on account or seasonal variations to be equal to 2 q and assuming further the number of fire streams required at any one time to be $2.5\sqrt{X}$ with 250 gallons per minute to each stream, the total capacity per minute required will be

$$Q = 250\,(2.5\sqrt{X}) + \frac{2 \times 40 \times 1000\,X^{1.14}}{1440}$$

or $$Q = 250\,(2.5\sqrt{X}) + 250\frac{X^{1.14}}{4.5}$$

or for fire purposes alone $F = 250\ (2.5\sqrt{X})$, and for ordinary purposes alone $O = 250\frac{X^{1.14}}{4.5}$

The ratio of the total capacity to the quantity for ordinary purposes is then

$$\text{Ratio}=\frac{Q}{O}=\frac{250\,(2.5\,\sqrt{X})}{250\,\frac{X^{1.14}}{4.5}}+1=1+\frac{11.25}{X^{0.64}}$$

Having obtained this ratio it will form a basis on which to determine the proportion of the plant that should be charged to the fire service and the rates for this purpose fixed accordingly.

For a city with a population of, say 30,000 inhabitants:

$$\frac{Q}{O}=1+\frac{11.25}{30^{0.64}}=2.276$$

Since

$$\frac{Q}{O}=\frac{D^2}{d^2},\ D=d\sqrt{2.276}=1.51\,d$$

D and d being the required diameters of the pipes to convey the respective quantities of water. In other words, where a four inch pipe would be sufficient for the conveyance of water for ordinary purposes, there would be required a six inch pipe for the conveyance of the combined supply.

In the above mentioned case it will also be seen that the pumping capacity would have to be more than double the capacity required for ordinary domestic purposes alone.

In the proportional amount of the total revenues thus determined to be paid for fire purposes should be included a reasonable amount to cover the cost of water used for other public purposes. As the water thus used is generally for the benefit of the whole community, it should, in the writer's opinion, be paid for by general taxation.

The above, as stated, serves only as an illustration of a method that may be adopted in cases of properly designed systems. Each case, however, requires its own particular treatment.

The main thing is to ascertain that part of the investment in a water works system which constitutes the excess for fire protection as this will serve as a basis for the computation of the proper hydrant rentals.

Having thus arrived by a proper method at the amount which ought to be charged for hydrant rental and having ascertained the total compensation to be paid in the case of a private company, by deducting from this total compensation the amount of hydrant rental, the total amount to be paid by private consumers will remain and rates for service can be figured which will be fair alike to the consumer and to the company.

TUBERCULATION AND THE FLOW OF WATER IN PIPES

Nicholas S. Hill, Jr., C. E.

I wish to disclaim any credit for originality at the inception of this paper and thereby remove any possible criticism on that score. In fact, the introduction of matter which has been hashed and re-hashed in the transactions of various technical societies as well as in the technical journals seems unavoidable. These data, however, form the available stock in trade for use under circumstances like the present. Many of the ideas presented herein have been suggested by the perusal of papers and discussions on kindred topics. Having made an extensive search I have been able to correlate much fragmentary matter, thus giving a a new significance and force to information which we have all probably acquired, from time to time, but never before segregated.

It is remarkable to find how little is known, or has been written, about tuberculation and the deposits and growths which occur in water mains. The absence of available data on a subject so important, from the viewpoint of economical design and efficient operation, speaks poorly for the initiative, invention and care of hydraulic engineers and water works superintendents.

I wonder for how long a time water works engineers and superintendents will be willing to bury their distribution systems under four feet of earth and leave them to rust, corrode, fill up and putrify, without means of access for inspection or cleaning? Why do we do it now? Is there one present who can give an intelligent reason? —COST— This answer is invalidated as we shall see. There is but one other—CUS-

TOM; HABIT.— This acknowledgment leaves no room for escape. We condemn ourselves as creatures of habit—atavistic, meticulous. We have let our younger brethren of the electrical profession outstrip us. Born without precedent they have evolved their methods to meet necessities. Their conduits have manholes. Their cables, or pipes, have provision for testing to determine loss of head, leakage, etc. They measure the fluid delivered to the consumer and pumped from the station. They fully realize an excessive loss of head means a heavy coal consumption which in turn means great expense. They realize waste means more pumpage, and hence more coal, so they design their distribution with means for inspection provided. Intelligent inspection which produces certain knowledge, which reduces cost and increases efficiency.

What do we know? A few cities and towns keep intelligible data regarding the costs of pumping, still fewer give us information regarding the meteorological conditions of the water shed. We usually have estimates of the per capita consumption, which are meaningless unless this consumption is subdivided into its various uses. Occasional reports are issued giving good data on filtration, but these are so rare that unless you write for one before you stop reading the notice of publication you receive a reply—"exhausted."

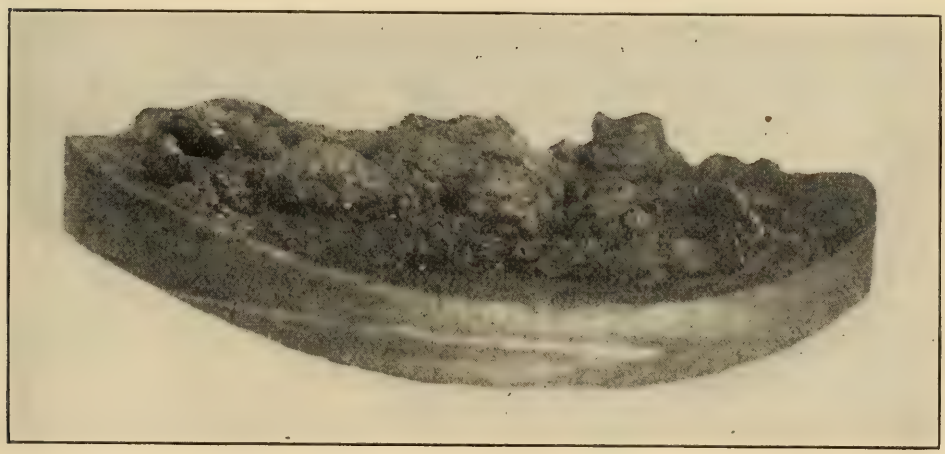
There is no uniformity in the method of compiling statistics so that your information is useless for purposes of comparison. How many times have you encountered a nicely ruled page, headed "Cost of Pumping," with columns for "hours pumped," "coal used," "gallons pumped," "salaries," "cost of coal," "cost of repairs," "cost materials and supplies," etc., etc.? You turn your eyes to the end of the page in great anticipation and find "Cost per Million Gallons." You hunt from cover to cover of the report and nowhere is there an intimation of the head pumped against.

What has the above to do with the subject matter? Simply this. My purpose in submitting this paper is to

focus attention upon a subject which is ripe for consideration, in the hope that interest may be stimulated thereby, and further, if my endeavors are fruitful, to prevail upon those engaging in investigations to *standardize the results of their efforts.*

I intend, therefore, with some trepidation (lest I awaken the dormant jealousy of some "formulist" with a pet formula of one class or another) to discuss with as much brevity as possible the available formulas for our purposes, after treating the question of tuberculation.

I wish it understood for the benefit of those addicted to formulism, that the data herein submitted are not all applicable to actual examples. They are given with a view to accentuate the points elucidated rather than for practical use.



TUBERCULATION AND DEPOSITS IN PIPES

What is tuberculation? How produced? How prevented? How palliated? I am free to confess a search for information on these subjects has been fruitful of small results.

The various deposits which lessen the carrying capacity of water pipes and conduits may, however, be divided into three classes:

(1.) Incrustations, commonly known as tuberculation, on unprotected or imperfectly protected iron pipes.

(2.) Deposits or growths on the inner surface of iron pipes, whether protected or unprotected, and of conduits, rock tunnels and other channels; the nature of the deposits depending on the chemical constituents or biology of the water or both.

(3.) Accumulation of debris and mud in inverts, hollows and dead ends.

I. TUBERCULATION OR RUST.

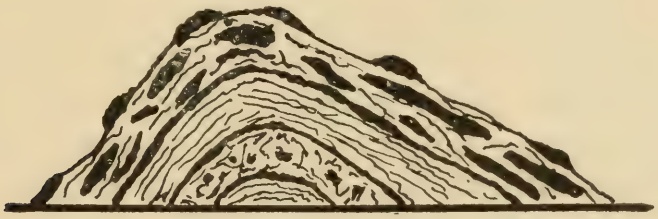
Incrustations are formed by the corrosion of iron pipes, valves and other iron work where the inner surface is not protected, or is imperfectly protected. These incrustations begin as minute projections dotted over the surface in varying number—sometimes in rows, generally in an irregular manner. In form they resemble small asymmetrical cones or limpets, often with a steep and a more sloping side. They grow by addition in concentric layers. The steep side faces the current. They increase in size and numbers, until they ultimately become confluent and form a coating of considerable thickness. In uncoated pipe this kind of incrustation may be nearly uniform from the beginning, in which case nodules are not seen, but the nature of the incrustation is the same.

A pipe of small diameter is sometimes completely choked by the incrustations. In large pipes the thickness of the deposit seems to be limited. When about one inch to one and one-half inch thick it does not seem to increase, and if so the increase is slight. This is probably owing to the density of the incrustation acting as a protection. If the incrustation is removed, or if the conical tips of the limpets are broken off, it begins to grow with activity as originally. I do not know that I can do better than to repeat Dr. Brown's* description

*J. Campbell Brown, Proc. Inst C E Vol. 156.

of the formation of these limpets as it is applicable to samples derived by the author.

"The central portion of the limpets shown in sketch below is black when fresh and soft.



Yellow. Core, Black, Soft. Soft and Yellow.

It often contains a little sulphide of iron as well as oxide; it becomes red on exposure to the air; the middle layers are of the orange red, ferric oxide, and sometimes contain iron organisms of the well known rosary form, which a high magnification resolves into a double, ribbon shaped spiral, twisted closely upon itself. The limpet shaped cones vary in consistence; when well developed they are hard outside and softer within. The outer concentric layers are denser, sometimes quite hard; they are composed of ferric oxides but include hard black layers of magnetic oxide of iron, in which dead organisms can occasionally be found." As a rule when the nodule has been taken away from the water the dark central portion when dry goes to a soft powder and the outside layer changes by oxidation to the brownish red color of the middle layers.

Frequently the carbuncles taken from a pipe coated with asphalt have a cavity in the under surface as shown below, being attached by their edges.

This form may be caused by the blistering of the coating through the collection of air or other gases, thereby preventing the central portion of the carbuncle from touching the iron.

Tuberculation is not a result of iron organisms, although there seems to be some confusion as to the effects produced by them. The author is inclined to the theory that these nodules are a modified form of rust, the growth of which may be accelerated by the carbonic acid liberated by organisms present in the water. Their presence in the composition of the limpets is mechanical rather than biological in many instances, and the presence of organisms is not essential to their growth. Dr. Brown's researches showed that "Organisms are found in some incrustations and may modify their composition; on the other hand, incrustations are often free from every trace of life. They occur equally in waters which contain no iron organisms (Nos. 1 and 3, Table No. 1.) and in waters from which all organisms have been removed by filtration. (Nos. 1, 4, 5 and 12, Table No. 2.)" This theory is corroborated by many other authorities and seems rational.

These incrustations have also been referred to acids in the water acting on the iron in the pipes, but Dr. Brown found that although acid waters and waters containing manganous salts hasten the corrosion of the iron, nevertheless, incrustation is formed not only by acid waters (Nos. 1, 2, 3, 12, 13, and 17, Table No. 2.) but by water which is neutral (No. 7.) and even alkaline (Nos. 5, 9, 14 and 15.) The incrustation varies in different districts. Soft water seems to augment the corrosive action not because the water is soft, but it so happens that soft water is more commonly acid than hard water, and hence the effect has been frequently attributed to softness. As a rule, in the East, well waters do not have as great an effect on pipes as surface waters, possibly because they are usually harder. Filtered water, under certain conditions, seems to have less corrosive power than unfiltered. On the other hand, some ex-

TABLE No. 1

Analysis of Incrustations

	Young Incrustations Produced in 5 months on uncoated iron pipes by No. 12 Water containing no iron Organisms, its acidity neutralized by lime	Old Incrustations on iron pipes from No. 9 Water which contains no iron Organisms and has Alkaline reaction	Conical Incrustations containing a hard magnetic layer, but no soft Orange layer and no Sulphide No. 9 Water Alkaline reaction	Old Incrustations containing black sulphide in center and an Orange layer, with rosary shaped Organisms. No. 9 Water Alkaline reaction	Incrustation removed from Iron Pipes by a scraper
	1	2	3	4	5
	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
Moisture	2.62	9.40	5.61	4.88	2.74
Loss on Ignition	24.19	20.50	21.38	18.34	10.96
Ferric Oxide $Fe_2 O_3$ and $Fe_3 O_4$	57.95	61.87	58.48	59.46	76.20
Ferrous Oxide Fe O	9.17	4.15	8.78	14.40	
Lime	2.06	0.56	0.23	.....	0.075
Magnesia	trace	none	.....	0.10	trace
$S O_3$ combined	1.43	0.80	0.32	0.20	0.28
Sulphur	trace	.....	0.34	0.05	
Insoluble in Hydrocloric acid	2.58	1.79	4.81	1.55	7.20
Undetermined	.....	0.93	0.05	1.02	2.545
	100.00	100.00	100.00	100.00	100.00

—From paper by J. Campbell Brown, Proc. Inst. C. E. Vol. 156

TABLE No. 2=ANALYSIS OF WATERS.

(Expressed in parts per 100,000)

	No. 1 Water Rivington	No. 7 Water Loch Katrine	No. 9 Water Dee, Aberdeen Shire	No. 12 Water Vyrnwy	No. 2 Water Elan Valley	No. 3 Water Another Welsh Valley	No. 4 Water Ireland	No. 5 Water Ireland	No. 6 Water Lancashire	No. 13 Water Taff	No. 14 Water Montgomeryshire	No. 15 Water Ontario	No. 17 Water Lancashire
Total Solids	10.10	3.61	6.1	3.98	5.44	5.6	6.72	9.92	34.8	4.8	16.06	18.48	10.44
Loss on Inquition	2.74	1.18	1.9	1.05			3.04	4.52				5.16	
Alkalies	1.06	0.501	1.36	0.518									
Magnesia	0.461	0.205	0.256	0.127									
Lime	1.735	0.509	0.48	0.706									
Oxides of Iron Fe_2O_3	0,016	0.002	None	0.099	0.016	Small Quantity	0.004	0.008	Trace	Small Quantity	Trace	0.006	Small Quantity
Oxides of Iron FeO		None			None								
Manganese Oxide	0.017	None	None	0.059	Trace	Trace			Trace	Trace	None	None	Trace
Chlorine, combined	1.5	0.711	1.14	0.6					3.0				1,3
SO_3 combined	2.144	0 435	0.476	0.6									
Silica	0.463		0.361	0.214									
Total Mineral Matter	7.417			2.923							Large		None
C. O. combined	None	0.308		None	0.46		0.176			None	quantity		
Organic Carbon	0.343	0.21		0.498									
Organic Carbon After Filtration	0.323			0.331		0.6			1.109				
Organic Nitrogen	0.064			0,064		0.1			0.124				
Organic Nitrogen After Filtration	0.052			0.042									
Nas Nitratis	Trace	0.005	0.02	0.109									
Acidity, as (Ca. O)	0.1	Almost neutral, Alkaline after boiling	Alkaline	0.2	0.225	0.22	Acid before boiling Alkaline after	Alkaline	Alkaline	Slightly Acid	Alkaline reaction	Alkaline	Slightly Acid
Oxygen per litre				5.45 c. c.									
Nitrogen Gas per litre				11.53c. c.									
CO_3				None									
Hardness					2.21°		1.95°	4.03°	14.0°				

From paper by J. Campbell Brown, Proc. Inst. C. E., Vol. 156.

perimenters suggest that alkalinity dissolves the asphaltic coating.

No satisfactory explanation has been found, nor is there any unanimity of opinion as to the cause of the differences between the rust nodules in water pipes and other forms of rust.

ANALYSIS OF INCRUSTATIONS

Contain in 100 parts of the dried material:

	No. 1 N. Y.	No. 2 Rockaway	No. 3 N. J.	No. 4 Wash'gton	No. 5 Phila.
Ferric oxide	78.92	60.47	74.29	73.47	73.91
Ferrous oxide	11.35	5.30	8.63	4.36	5.09
Combined water	8.30	6.19	11.83	13.18	13.17
Moisture			1.98	1.04	1.42
Organic matter	0.22	1.66			
Silica & sand	1.17	26.36	2.70	7.68	4.41
Free sulphur			0.13	0.18	0.61
	99.96	99.95	99.56	99.91	98.61

Carbonic anhyd.
Phosphoric anhyd.
Manganese and Alumina
Traces in all samples.

All samples strongly magnetic.

Analyses by J. Lainson Wills, F. C. S., analytical and technical chemist.

The examination for micro-organisms only show presence of the common rod (putrefactive) bacteria with the exception of No. 5 which gave also a development of Leptothrix Ochracea (Kutzing) (Chlamydothrix Ochrocoea.)

Mr. Whipple in the Proc. of the Am. W. W. Ass'n, 1904 p. 159, suggests a slightly different theory than the one herein suggested. He says "I think the question of incrustation of pipes is largely a biological one."

There are some other instances where tuberculation occurs by itself alone; there are other cases where it is

complicated with the presence of iron and crenothrix in the water, and there are many more cases where it is complicated by the growth of "pipe moss" and a variety of other organisms. In the latter case the action that takes place is something like this: These growths of organisms occur on the pipe walls and between them and the walls there is a layer of air from which the oxygen is at times temporarily exhausted and where carbonic acid may be in very large amount, this condition being brought about by the organisms. When these organisms are broken off there is a little spot on the pipe where the iron may be exposed to action of carbonic acid. Then again when the iron becomes oxidized it may be deposited around these spots in crystalline form. Hematite, you will remember, crystallizes in a botryoidal form. So the tubercles are really crystalline deposits of iron, mixed up of course with a great deal of extraneous matter."

Of one thing I am satisfied, that tuberculation will not occur when the iron is effectively protected by any means from contact with the water. The iron of the incrustations is in all cases derived from the iron of the pipes. Tuberculation is found in water containing no iron in solution such as (Nos. 7, 9, 14 and 15, Table No. 2.) The iron of the pipe is dissolved out where tuberculation occurs and the iron is frequently soft, black and spongy beneath the limpets. In other words, where tubercles are found the iron of the pipe shell is wasting away by oxidation.

The following analyses of Rust will facilitate a better understanding of the phenomena involved:

(a)

Volatile or Combustible Matter	16.62%
Sulphuric Anhydride $S O_3$	0.60%
Phosphorix Anhydride	Trace
Magnetic Iron Oxide $Fe_3 O_4$	32.47%
Iron Oxide $Fe_2 O_3$	9.04%
Insoluble Sandy Matter	41.27%
Lime Ca O	Trace
Total	99.98

(b)

Volatile or Combustible Matter	18.05%
Sulphuric Anhydride SO_3	1.08%
Phosphoric Anhydride $P_2 O_3$	Trace
Magnetic Iron Oxide $Fe_3 O_4$	0.36%
Iron Oxide $Fe_2 O_3$	37.55%
Insoluble Sandy Matter	42.78%
Lime Ca O	0.18%
Total	100.00

(c)

Sulphuric Anhydride $S O_3$	1.44%
Phosphoric Anhydride $P_2 O_3$	——%
Magnetic Iron Oxide $Fe_3 O_4$	——%
Iron Oxide $Fe_2 O_3$	70.05%
Insoluble Sandy Matter	——%
Lime Ca O	0.37%
Moisture	13.60%
Combined water and organic matter { Volatile, Combust. matter }	11.39%
Magnesia Mg O	Trace
Silica $Si O_2$	1.09%
Combined Chlorine	Trace
Carbonic Acid $C O_2$ (Aqueous solution of carbonic dioxide	2.12%
Total	100.03%

A comparison of these analyses with the "Analysis of Incrustations," (Table No. 1, p. No. 309) shows:

The variation in the composition of this rust is chiefly due to the degree of oxidation of the iron, as well as to the character of the solid matter suspended, and to the chemical constituents contained, in the water, which becomes mechanically mixed with the rust, by deposition, or the action of organisms, or by magnetic influences.

Referring again to the effect of organisms, Dr. Brown says: "Many incrustations contain no organisms; but so far as my observations go, when present, organisms

appear to modify the composition of the limpet. The rosary shaped form does not belong to one organism only, but it is assumed by several different organisms at a certain stage of growth. Wherever it occurs I have always found the usually black iron compound converted into red ferric oxide." It is not uncommon to find a stratum of dead organisms close to the hard magnetic oxide layers near the exterior.

The chemical action in the formation of rust is as follows:

The iron is first attacked by the carbonic dioxide and water and forms ferrous carbonate, thus:

(1) $Fe_2+2\ C\ O_2+2\ H_2O = Fe\ CO+2H_2$

The ferrous carbonate is then dissolved by the excess of carbonic dioxide in the same manner as CaCo is held in solution in the chalk water. Ferrous carbonate being a very unstable compound, is quickly oxidized by the oxygen in the water, and forms Ferric Oxide $Fe_2\ O_3$ and carbonic acid gas thus:

(2) $2\ Fe\ C\ O_3+O = Fe_2\ O_3\ 2+C\ O_2$

It will, therefore, be seen that a similar amount of carbonic dioxide gas is given off in (2) to that used in (1), so it follows that a small quantity of carbonic dioxide suffices to keep up the reaction.

Ferric oxide is not magnetic but ferrous carbonate is, and possibly this magnetism plays some part in the rusting of water pipes.

It is to some extent possible to trace out the source from which the chemical constituents of the rust nodules is derived. For this purpose an analysis of "Grey Pig Iron" is submitted below:

Iron	94.56
Graphite Carbon	3.10
Combined Carbon	0.04
Silicon	2.16
Sulphur	0.11
Phosphorous	0.63
Manganese	0.50
	101.10

Referring back to analysis (c) we find the percentage of iron in the rust is 49.03%, for the rust is composed of 70% by weight of iron Oxide (Fe_2O_3). The atomic weight of Iron=55.9 of oxygen×15.96,

Fe_2 signifies 55.9×2 parts by weight of Iron.=111.8
O_3 signifies 15.96×3 parts by weight of Oxygen.=47.88

159.68

$\therefore$ $111.8\div159.68=70\%$ Iron in $Fe_2\ O_3$

$70\%\times70\%=49$ per cent in the iron rust.

This leaves 50.97% for matter that has been deposited. This latter amount is composed of lime, organic matter, silica, carbon dioxide, etc. A portion of the carbon, sulphur and silica is probably obtained from the cast iron, whilst the other remainder is extracted from the solid matters carried in the waters.

In this manner the actual loss of iron by tuberculation or rusting may be estimated. Referring to Table No. 4, p. 323 we find the Washington 6″ main, 35 years old, delivered 44 cubic inches of nodules per foot=135 cubic feet per mile. Now as these nodules contain 49% by weight of iron and a cubic foot of the incrustation weighs 93 lbs., the total loss of iron equals 3.07 short tons per mile or 176 lbs. per mile per annum. As a mile of average 6 inch pipe weighs 86.5 tons the total loss equals 3.5%. This, however, must not be taken as the actual loss, the iron beneath the nodules may be soft and spungy so the strength of the main is more seriously affected than these results indicate.

Generalization from a specific example is dangerous. The character of the pipe coating as well as the source of water supply and the chemical constituents of the water, severally and individually, affect the conditions in different localities, as shown in Tables No. 1, 2, and 3, pp. 309, 310, 323.

Examples of the space occupied by rust together with the age of the pipe will be found in the table below. This space is ascertained by filling the pipe with water, noting the quantity, and deducting it from the capacity of the pipe when cleaned.

No.	Age of Pipe Years	Diam. of of Pipe Inches	Amt. of Rust per ft. Cu. Ins	Capacity of Clean Pipe per Lin. foot Cu. Ins.	Per cent of space occupied by rust
	29	4	60.79	150.33	40
	22	4	81.45	150.33	54
	14	6	60.00	326.68	18
	15	6	63.33	326.68	19
	16	10	80.00	941.76	8.4
	30	16	440.00	2419.20	18

We have seen that tuberculation arising from rust, or oxidation of the iron in the pipes, and forming the characteristic limpets or nodules may be affected to some extent by micro-organisms or the chemical constituents of the water.

Highly alkaline waters, containing calcium and magnesium, may form deposits which seem to prevent tuberculation, but these deposits may in themselves be almost as objectionable as the rust nodules. It is safe, however, to state as a general proposition that no chemical treatment, which does not incur results equally as objectionable, not even the neutralization of acid waters by slight excess of lime or caustic soda, prevents the corrosion of iron pipes. The only effective treatment is to provide a coating for the iron which will preclude oxidation and withstand the solvent action of certain waters upon the coating. It is possible to remove the incrustation as it forms by scraping and whereas this process has not been generally used in this country, mains have been successfully cleaned by the use of scrapers.

2. DEPOSITS AND GROWTHS DEPENDENT UPON THE QUALITY OF THE WATER.

(a) **Deposits or incrustations due to alkalinity.** Limestone, shale, and other rocks, from which water dissolves salts of calcium and magnesium, produce waters which contain a large amount of mineral matter. These salts of calcium and magnesium produce what is termed "hard water." They are divided into two classes, which produce temporary and permanent hardness respectively. The carbonates and bicarbonates of calcium and magnesium produce temporary hardness. These carbonates and bicarbonates are spoken of as "alkalinity." Permanent hardness is effected by sulphates, chlorides, and nitrates of calcium and magnesium. With the insoluble salts producing permanent hardness we have little to do, although, no doubt, many of us are familiar with their scale forming properties when concentrated

by evaporation in boilers. The calcium and magnesium carbonates, called carbonates of lime and magnesia, are almost insoluble except in the presence of carbonic acid ($C O_2$). They are, however, soluble in water in which a large quantity of carbonic acid is dissolved, giving rise to double carbonates or bicarbonates of these compounds. Carbonate of lime is usually present in larger quantities than carbonate of magnesia and is more potent in forming incrustations in water mains, although both are frequently found in combination. The first and chief deposit, therefore, depending on the chemical composition of the water, is the translucent semicrystallized scale of calcium carbonate. Prof. Roscoe states in his treatise on chemistry, (V. 11. Pt. 1, P. 209,) that "one gallon of water saturated with carbon dioxide (commonly called carbonic acid) dissolves at 50° F. 51 grains of calcium carbonate. The solubility increases under an increase of pressure, up to 175 grains per gallon. If such a solution be allowed to stand at the ordinary temperature, six sided prisms, having the composition $CaCO_3+5\ H_2O$ (Carbonate of lime and water) separate out. These crystals which lose their water at 66° are sometimes found in the pipes of pumps and also adhering to confervae in ponds." Dr. Brown attributes the formation of these crystals to the escape of carbonic acid gas from water containing bicarbonate of lime. Whatever the cause this scale is found in large quantities in some places and owing to the increased solubility of the carbonates under pressure the deposits in pipes should be greater at high points.

It is needless to go into further details regarding these deposits as they are found chiefly in limestone countries where everyone is familiar with their nature.

The effect of these deposits vary in different localities. The following analysis of water and deposit is from Bath, England.

	Part per 100,000
Carbonate of lime	32.15
Carbonate of magnesia	1.68
Sulphide of lime	12.30

Sulphate of soda	0.78
Chlorides of sodium & potassium	5.50
Oxide of iron, silica, etc.,	0.70
Organic matter	0.79
Total solid matter	53.90

Hardness of water before boiling	35.1
Hardness of water after boiling	14.6

Analysis of deposit:	
Carbonate of lime	97.58
Sulphate of lime	1.32
Oxide of iron, etc.,	1.10
	100.00

Two inches in length of 6″ pipe contained 26,786 grains, or 23 lbs. per foot equals 5.4 tons per mile. At Southampton, Eng., where the water is derived from wells sunk in chalk, the coating is of pure calcium carbonate.

Mr. Le Conte states regarding the mains in San Francisco, "Pipes which have been in use for ten or twenty-five years generally show a lime scale on the inner surface, making it somewhat rougher than the new surface of asphalt, but no material change in the value of C has been noted as yet for the larger size pipes."

The ancient Roman aqueduct of the Pont du Gard in France furnishes an excellent example, where a lining about one foot thick was formed in the course of centuries and the carrying capacity reduced by something like one half.

Boiling the water or agitating it hastens the deposition and it is safe to assume that the temperature of the water in the pipes materially affects this action. Confervae, Desmids, and other plants sometimes form a slimy layer on the inner surface of cold pipes, through which calcareous waters flow.

The universal practice in removing temporary or

carbonate hardness is to add a suitable quantity of milk of lime, or lime water, according to the Clarke process, and run off the clear water after settlement. The lime water combines with the free carbonic acid and the "half bound" carbonic acid which holds the majority of the lime in the water in solution. It precipitates not only the lime originally present in the water in the form of a bicarbonate, as a fine, granular solid, but also the lime which was added to the water.

Expressed in chemical notation the action is as here represented:

Bicarbonate of lime	+	Slakes Caustic lime
$\left\{\begin{matrix}\text{CaO, } CO_2+CO_2 \\ 144 \\ \text{Soluble}\end{matrix}\right.$	+	$\left\{\begin{matrix}\text{CaO, } H_2O \\ 74 \\ \text{Soluble}\end{matrix}\right.$

Carbonate of lime	+	Water
$\left\{\begin{matrix}2\ (\text{CaO, } CO_2) \\ 2\times 100 \\ \text{Insoluble}\end{matrix}\right.$	+	$\left\{\begin{matrix}H_2O \\ \\ 18\end{matrix}\right.$

In this reaction a weight of 100 of carbonate of lime is held in solution by 44 parts of carbonic acid=144. There is added 56 of hydrated caustic lime with 18 of water=74. The 56 parts of lime combine with the 44 parts of carbonic acid and become 100 parts of carbonate of lime. The loss of the extra 44 of carbonic acid leaves the original 100 parts in the form of the insoluble carbonate and hence 200 parts of carbonate of lime are precipitated. When carbonate of magnesia is encountered, a sufficient additional quantity of lime must be added to decompose the carbonate of magnesia into hydrate, thus:

$$\underbrace{Mg\ CO_3+Ca\ H_2O}_{\text{Soluble}} = \underbrace{Mg\ O\ H_2O+Ca\ CO_3}_{\text{Insoluble}}$$

Magnesium Carbonate+slaked caustic lime = magnesium Hydrate + calcium Carbonate.

(b) **Ferruginous slime, "Pipe moss," sponge, etc.**

In addition to the reactions occurring in water pipes previously described, there are also biological reactions. These reactions are interactive, that is to say, the passage of water through pipes affects the biology of the water and the water produces certain growths in the pipes. With the first question we need not deal except in so far as it enables us to conclude that a clean reticulation system, not only affords better pressures, but is conducive to a potable water and removes many causes of complaint due to an unpalatable and olfactory supply.

It is well known that the number of microscopic organisms is reduced in the passage of water through pipes and, at certain seasons, the bacteria as well. This is attributable to several causes, the first of which is sedimentation. Many microscopic organisms are heavier than water and settle in pipes whenever the current is reduced to a certain point. Others which usually rise to the surface in ponds and reservoirs, on account of the gas bubbles which they contain, deposit in pipes when the water pressure has deprived them of their gas. Many of us are familiar with the malorodous conditions sometimes existing at dead ends, which may be accounted for to a great extent by the deposition of organisms and particles of amorphous matter at these points. They also tend to deposit on up grades. It has often been observed that water at high points in the distribution system contains fewer organisms than at low points.

Ferruginous Slime. Probably the most serious biological effect produced is due to the so called iron organisms belonging to the Crenothrix group. There seems to be a number of organisms belonging to this group, and distinctive names have at different times been applied to them. The results they effect seem to be slightly differing, chiefly as to the solidtarity or firmness of the slime they produce, although this may be due to extraneous causes. In some places this slime is easily disengaged from the pipe walls and floats away in flocculent masses, which seriously impede the service

pipes, etc. In others the coating seems to be more permanent and in many places in England an annual cleaning with brushes or scrapers is resorted to for its removal. There seems to be two principal species—Crenothrix Kuhuiana and Chlamydothrix, sometimes called Ochracea. This first species has been described by Prof. Erastus G. Smith, in the proceedings of this Association for 1903, page 524. The deposit occasioned by these organisms is sometimes black, sometimes reddish brown or yellowish brown; the shade or color is effected in great measure by the presence of manganous and manganic oxide. ($Mn\ O$ & Mn_2O_3). The slime or deposit lines the sides of the pipes sometimes to the thickness of an inch. It contains a great deal of iron (See analyses Table No. 3, P. No. 323). The iron, however, is **not** derived from the pipes as is the iron of rust nodules previously described. This deposit occurs on stonework, wood work, brick and rock surfaces where the water has never been in contact with iron work of any kind. It is hardly necessary to controvert theories, heretofore held, that this deposit is attributable to the deposition of matters held in suspension in the water If this were true, gravity would be the cause and the deposit would be found at the invert. Dr. J. Campbell Brown, in the paper previously mentioned, states: "The slime here referred to forms as thick a layer at the top and on the sides of pitch coated pipes as at the invert. The composition is essentially the same all around the pipe, except that more siliceous and rock or clay particles are entangled in it at the invert." (See analyses No. 1 and 2, Table No. 3, P. 323). "The water always contains iron when the slime is found. (See 2, 3, 12, and 13, Table No. 2, P. No. 310, while the water from similar gathering grounds, but containing little or no iron, does not produce this kind of deposit. (See 5, 7, 9, 14, etc. Table No. 2, P. No. 310. From the above it becomes apparent that iron is accessory to the development of the Crenothrix Kuhuiana and Chlamdothrix. As a matter of fact they demand, not only organic matter in the water to give tissue, but ferrous iron

(Notes Continued)

TABLE No. 3—ANALYSIS OF SLIME

	1 Sides of Pipe	2 Bottom of same Pipe	3 Same Pipe 11 miles further on	4 Slime on side of Protected Pipe (after 5 months flow direct from rock tunnel)	Slime Several Years Old: 5 Slime 19 April 1900	Slime Several Years Old: 6 Slime 14 miles further on, March, 1901	7 Mature Slime from No. 2 Water in protected pipe
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ferric Oxide	42.23	39.72	25.11	39.39	28.14	33.19	33.73
Ferrous Oxide	None	None	None	Trace	None	None	
Manganous Oxide	5.98	6.65	19.91	17.38	17.17	11.82	16.58
Manganic Peroxide	9.58	10.34	17.77	1.30	19.84	8.63	26.83
Lime	1.67	2.80	1.24	1.57	0.70	2.55	2.70
Magnesia	13.74	9.83	1.45	1.64	1.69	0.21	1.15
Sulphates	Trace	Trace	Trace				
Sulphides	None	None	None				
Loss on ignition combined water, animal and vegetable matter	26.80	30.66	34.52	33.63	27.67	42.12	19.01
Undetermined	.....	.....	.....	5.09	4.79	1.48	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sand and Insoluble Matter	24.66	37.18	36.70	43.89	48.04	13.27	14.23
Including Carbon	8.17	.....	9.98	.....	5.97		
Including Nitrogen	.....	.....	1.47	.....	0.85		

From paper by J. Campbell Brown, Proc. Inst. C. E. Vol. 6.

for food. Mr. D. D. Jackson, in an article in the "Journal of the Society of Chemical Industry," May 31st., 1902 points out that there are different kinds of Crenothrix each requiring different metals for sustenance, viz: Crenothrix Kuhuiana, Crenothrix Manganifera, Crenothrix Ochracea. The first precipitates in water, 31.6% F_2O_3 (Ferric Oxide); the second 33.9% Mn_2 O_3 (Red oxide of Manganese); the third 33.3% Ala O_3 (Alumina). This is interesting because we have organisms requiring other chemicals for sustenance. Thus: the Beggiatoa, Sulphates; Batrachospermun, Lime; Inactio, Silica, etc. It has been seen the Confervae and Desmids prosper in alkaline waters. So it is impossible to surmise how far the biological and chemical development in water mains is complex or interactive.

Dr. Brown watched the formation of the coating due to iron organisms by means of a microscope. "First there appears a living and growing jelly adhering to the surface of the pipes; dots and some months later, spirilla shaped organisms appear in this jelly. Iron begins to be deposited not on but in the jelly; and ultimately there are long threads in the jelly; which acquire a sheath. The sheath thickens by deposition of iron oxide, and the living thread elongates more and more, the sheath following up the thread. A tangled mass results; The older portions become more tangled and dense; and all the time particles are mechanically entangled. Finally the organism dies at the older end and breaks down, losing its form and becoming a gelatinous, flocculent mass of dark ochreous deposit, with the younger sheaths and living threads growing out of it. Treated with oxalic acid at this stage, the metals are dissolved, and disclose faintly the broken down and shapeless carbon compound of the disintegrated threads, some of the sheaths occasionally remaining visible."

Of the amount of iron or other minerals required to sustain these growths little knowledge is to be had. Mr. Hazen states three hundredths of a part in 100,000 of metallic iron very rarely precipitate or cause any trouble. Five hundredths occasionally precipitate and

this amount may be taken as the allowable limit in satisfactory water. This statement did not refer specifically to the development of the iron organisms, but in view of their possible development it is interesting to note that water (No. 2, Table No. 2, P. No. 310) containing only .016 parts of $Fe_2 O_3$ (Ferric Oxide) in 100,000 = 0.0112 parts of metallic iron per 100,000 yields much of this deposit. Of the waters listed in table No. 2 four, Nos. 2, 3, 12, and 13 are favorable to the development of iron organisms.

Referring again to Dr. Brown's paper, he states: "It is evident that acidity other than carbonic acid always characterizes water which produces this ferruginous slime; alkaline water never grows any, so far as the author has seen nor does neutral water. Bicarbonates which imply lime and magnesia seem to be opposed rather than favorable to their growth; organic matter alone does not produce it; and a trace of iron in neutral and alkaline water is quite consistent with the absence of slime. But an appreciable quantity of iron in solution in combination with organic matter of an acid character is an invariable accompaniment."

Unfortunately, Prof. Smith did not submit analyses of the water at Freeport, Ill., West Superior, Wis., and Wassau, Wis., where he encountered the Crenothrix. These analyses would be interesting for the purpose of verifying the conclusions reached by Dr. Brown. The information upon the question of the development of these organisms is, so far as I have been able to discover, meagre and unsatisfactory. This fact adds another link to the chain of evidence showing that the collection of data regarding the deposits in pipes would yield many benefits.

Crenothrix has been more frequently detected in ground waters, in the United States, as at Jamestown, N. Y., and at Brookline, Watertown, and other places in Massachusetts in addition to the places mentioned in Prof. Smith's paper, although it occurs also in surface waters, notably in the rivers Spree and Maas in Germany, and the

Chalamydothrix has been reported in the surface water supplies of many English towns. Crenothrix and Chlamydothrix seem to grow chiefly in drainpipes, deep wells, pipes and other badly lighted channels. Crenothrix possesses the power to increase very rapidly, so that in a few months after the introduction of its germs it covers the pipe walls to quite a thickness. In fact its development in many cases has been sudden and without warning, causing serious inconvenience and many complaints. It is noteworthy that Crenothrix is so commonly found in well waters which may be said to have passed through a process of natural filtration. I have not been able to discover, however, a well authenticated case of the development of either form of iron organism after efficient artificial filtration. Dr. Brown, however, states: "There is evidence of a growth of organic jelly, containing oxide of iron, forming a thin film in pipes beyond efficient filter beds; and it is conceivable that this may, after the lapse of sufficient time, grow in the same manner as before filtration, though at a much slower rate." At Rotterdam the water was taken from the River Maas and clarified by means of sedimentation and filtration. These works were established in 1874 and furnished a clear and sufficiently satisfactory water until suddely in the spring of 1887 the Crenothrix Kuhuiana appeared in great quantities.

At Freeport, Ill., mechanical filtration with the use of lime water as a coagulent, using from two to four grains of lime per gallon, has been successfully tried as a preventive.

Efficient filtration removes the food of the organism and neutralization of the acidity of the water by lime seems to introduce conditions fatal to its growth.

In England scraping the mains has been successfully tried and in many places this process will be found useful, not as a preventive but in maintaining the pipes in good condition.

"Pipe Moss." This biological phenomena is probably encountered much more frequently than the slime deposits due to the Crenothrix. Like the rust nodules,

it is more permanent and does not generally make its presence felt by precipitating floating, flocculent masses, which immediately arrest the attention of consumers and create complaint from stoppage of service pipes, discoloration, etc., Mr. Whipple, however, (Proc. A. W. W. Ass'n, 1904, P. 158) records an instance in Brooklyn where a change in the direction of flow in the water broke off the filament of the organisms attached to the walls and the network passed down the mains and lodged in the service pipes, causing the collapse of two boilers supplied by 2 inch services. The pipe moss in Brooklyn was an animal form known as Paludicella belonging to the Bryozoa, also called Polyzoa. The term Polyzoa, which means many animals, is highly appropriate for the group of aquatic forms which we now take up, for they, with a very few exceptions, form colonies composed of many individuals united in a common stock. Bryozoa, the name we shall apply, signifies "moss-animals," a term no less apt. Bryozoa are found under widely differing conditions. They form moss-like aggregations, which frequently attain considerable size, and are found attached to some submerged object. In form they vary greatly, forming branching tree-like colonies, some spreading out in flat sheets over the surface of submerged objects while others form soft and moss-like sheaths. Some of them are covered with a secreted coating or sheath which takes the form of a narrow brown-colored tube. The Bryozoa increase by a process of budding which gives rise to branched stalks. Statoblasts, or winter eggs, form within the body and escape after the death of the animal.

The fresh water genera of importance to our subject are, Fredericella, Plumatella and Paludicella.

The coating or growth developed by these Bryozoa, in pipes, occurs in branching interlaced filaments which take the direction of flow of the current as well as a sort of brown matting, covering large areas to considerable thickness. This matting has a rough surface, ap-

preciably diminishing the flow, and when dried resembles a piece of coarse burlap.

Filtration is the permanent remedy as before for the reason that these organisms as well as others which thrive in water mains depend upon the algae, protozoa, etc., contained in the water for their food supply. This deposit is also readily removed by a process of scraping or cleaning the main.

Sponge. The Spongidae, of which the fresh water sponges are a species, are really animals and lay eggs, as do many other organisms, which float down with the water and attach themselves in large quantities to the interior surfaces of the pipes. The famalies usually encountered in water mains are the Spongilla Lacustris, and Fluviatalis, of which latter the Myenia is one genera. The sponge dies during some cold spell in autumn, and their quick decay in large quantities is one of the principal causes by which the water supply of even a large city may be vitiated. The preservation of the species is accomplished by the statoblasts which retain their vitality through the winter. They develop in the late Spring. Two branches of the same sponge will unite if brought in contact and even two sponges of the same species will not infrequently combine to form a single specimen. These sponges grow very rapidly. Sponges do not thrive well in quiet water. They are firmly attached to the objects on which they rest. It very seldom occurs face upward and it is usually only on submerged surfaces, with face downward, or at least with no upward exposure, that these organisms thrive. Hence they are usually found on the top and sides of pipes. The color of sponges vary from light ochre to dark brown, gray or greenish. Greenish sponges contain chlotophyl, the green coloring matter found in green plants; and like these plants, green sponges grow only in situations accessible to light. ("Fresh Water Sponges, a Monograph,' by Edward Potts; Proc. Acad. Nat. Sciences, Phila. 1887. P. 158.)

The eggs or statoblasts of the spongilla mass themselves in traceries, like lace work, on the surface of the

pipe, varying in size, and the exterior boundary takes a circular or oval form. In time the eggs begin to bring forth sponge, which grows in circular patches. This growth if undisturbed gives out long fingers of sponge; which hang down across the pipes like a trellis or net, and effect a serious retardation of the flow. A very disagreeable cucumber taste is produced with the decay of the spongilla. I have seen mains filled with offensive masses of sponge closely packed between and around the tubercles. Mr. Emil Kuichling (Eng. Rec. Dec. 10, 1898,) describes the condition of the 36 inch Cast iron pipe of the Hemlock Lake Conduit at Rochester as follows:

"On entering the 36 inch pipe in the gate house, extensive organic growths were seen attached to the top and sides, while the lower part was considerably tuberculated. These growths increased in magnitude until they formed an almost continuous lining for the entire distance traversed (450 feet) with frequent large masses hanging from the top. A number of such pieces were noticed which were more than a foot square stretching like curtains across the upper part. The lining in general represented a dense fibrous mat may be 1 inch to 2 inches thick, and the glossy pitch coating of the pipe was visible only in a few places. Further examination showed these growths consisted of two species of Polyzoa and one of fresh water sponge which were identified by Prof. Dodge of the University of Rochester as Plumatella, Paludicilla and Myenia fluviatilis."

Flushing will not remove sponge; some form of scraper or wire brush is necesasry. While as before, filtration will possibly preclude its development.

Many other organisms are found in pipes, including: Protozoa as follows: Acineta, Amoeba, Arcella, Vorticella, Stentor and Zoothamnius: the "horn-polyps" or Cordylophora lacustris, and Hydra, of the Hydrozoa; of the Vermes, Nais; several forms of Rotifera; snails, mussels, etc. It is more common to find organisms of several groups cotemporaneously than to encounter separate species, thus Hugo De Vries in speaking of one

of the canals at Rotterdam said: "The walls were thickly covered with living organisms up to the water level. They formed an almost continuous coating of varying composition. There was a section of one of the canals, where a gentle current was flowing, which was a magnificent aquarium. The walls were everywhere covered with white tufts of fresh water sponge. Many of these tufts reached a diameter of six to eight inches, but most of them were somewhat smaller. Between the sponge patches were seated countless numbers of the mussel, Dreysenna polymorpha. Individuals old and young were often seen grouped together in colonies which sometimes extended completely over the sponges. But what most of all attracted attention was a luxuriant growth of the "horn-polyp." It covered the mussel shells and occupied all the space between the sponges. The stalks reached a length of an inch or more. On and between the Cordylophra swarmed countless numbers of Verticilla, Acineta and other Protozoa and Rotifera. These organisms had no lack of food material, and the absence of light protected them from many foes which in the light thin out their ranks. Over all these animals Crenothrix was found growing in abundance. The shells of the mussels and the stems of the "horn-polyp" were coated with a thick felt like layer of these "iron bacteria." In other localities in the pipes the place of the "horn-polyp" was occupied by the Byozoa or "Moss-animalicules."

This account, which is graphic, affords a forcible pen picture of the conditions as they exist in our reticulation system.

It has been frequently stated that these organisms growing in the pipes tend to improve the quality of the water by reducing the number of floating, microscopic organisms and bacteria. While this may be true, undoubtedly the result is achieved at an enormous sacrifice in the potableness of the water. With life there must be death and decay and the results of the decay of these growths is disagreeable, and sometimes obnoxious odors and tastes develop. In addition discol-

oration results in some cases as mentioned heretofore. The loss of head, due to friction and the dimunition of capacity offer more serious objections from a pecuniary standpoint. This is especially true where the supply is pumped. It is highly probable a coating one half inch thick will reduce the capacity of 6 inch pipe by 50% and of the larger sizes by 25% to 40%. This means one of four things: prevention, removal, additional mains or poor service.

There is reason to believe that all animals which inhabit the pipes are dependent upon organisms carried in the pipes for their food. It seems reasonable, therefore, that efficient filtration applied to the water, as it passes from the reservoir into the distribution pipes, would not only remove organisms from the water itself, by starvation and death, but provided the water were not again exposed to the light, it would prevent their growth. This method of removing these animals, however, may be likened to killing rats in the walls of your house by poison. It seems more reasonable when filtration becomes necessary, to give the pipes a thorough cleaning in advance and to avoid unloading the putrescent growths upon the consumer. After the pipes are cleaned the filters will retard further development

While filtration may remove all forms of organic growth and will certainly reduce these growths materially, it occurs to me that we are assuming some things of which we are not cognizant when we exploit this theory without modification. That filtration will remove the most common forms of animal life in pipes is well assured; there is no data to confirm or deny the development of other forms in time. Certain microscopic organisms grow in the drains of filter beds. Crenothrix flourishes in well water. As before stated, filtration will not prevent the formation of rust nodules.

(3). **Sedimentary Deposits.**

These deposits occur usually at low points or where the current is sluggish or nil. They consist of mud, particles of rock and clay and, as before stated, dead or-

ganisms. There deposition is mechanical and identical with the process effected in sedimentation basins. River waters which at times are roily frequently give trouble from this source. These deposits may be removed by any process which clarifies the water or by flushing and scraping.

Summarizing, the remedy or palliative for these various incrustations or deposits may be classified as follows:

Rust, tuberculation or rust nodules.	Perfect or improved pipe coating.	Cleaning by scraping.
Incrustation due to alkalinity.	Removal of carbonates by treatment with milk of lime, etc.,	Cleaning by scraping.
Biological formations due to organisms.	Filtration or filtration and removal of iron.	Cleaning by scraping.
Sedimentary deposits.	Clarification by sedimentation, filtration or otherwise.	Flushing, scraping.

PIPE COATINGS.

This subject is so closely allied to the question of tuberculation and so little attention is paid to it that this discussion would be incomplete without reference to it.

Various opinions exist as to the efficiency of pipe coatings, as we know them to-day. The extremes include those who claim tar or asphaltic coatings, properly applied, will prevent all tuberculation—and those who claim no such coating is a permanent protection. I think the manifest divergence of opinion regarding the effectiveness of pipe coatings as ordinarily applied is

due to lack of appreciation of:—first, the variation in the compositon and application of the coatings, and, second, the wide disparity in the chemical constituents of different waters. It is probable that some foundries are not even cognizant of the exact formula for the preparation used by them. More or less care is taken at different places in drying, heating, dipping, etc. Some waters seem to be particularly destructive of ordinary coating. But on this point there seems to be no close agreement. The following exemplifies this: Statement No. 1. "The alkalies, alkaline carbonates and ammonia have a solvent action on the pipe coating"; Statement No. 2. "The softness of the waters may be assigned as the chief reason for the specially destructive action." As a matter of fact, pipe coatings as applied in this country do not prevent rust per se. They may do so under favorable conditions. They do incease the resistance to corrosion. The extent of this resistance depends upon the character of the coating, the thoroughness of its application and the quality of the water. It is needless to consume your time in quoting authorities in support of these statements. I have no doubt your individual experience has led you to the same conclusion. There are, however, many, many papers by competent and experienced authors who attest to these facts. We must not, however, confuse the prevention of rust and organic deposits. No pipe coating, so far as I know, will prevent the development of slime, pipe moss, sponge, etc.

Our present coatings are only efficient for a varying term of years, and it therefore follows, that to maintain pressures as well as the quantity and quality of the supply, periodical removal of the incrustation is necessary. The pipes must be attended to regularly and systematically. The subject of coatings, equally with that of tuberculation and deposits, is ripe for serious consideration.

If more care were exercised in the application of coal tar pitch to cast iron mains infinitely better results could be obtained, and I may say, here, so far as the

author has been able to discover, no better coating for cast iron mains has been devised. The pitch used should be as free as possible from hydrocarbons as they either volatilize or dissolve by long exposure to water. It is well, before the application of the coating, in order to prevent rusting, to paint the pipe inside and out with linseed oil as soon as the sand is cleaned off, and while the pipe is yet warm. After inspection and proving, the pipe and specials should be heated in a suitable oven to a temperature of about 320°. The heating drives off any slight rust or dampness and allows the coating to penetrate the pores of the iron, which are opened thereby. And as the first coat is liable to have pin holes and air holes which become centers of nodules, the pipes and specials should receive a second coat. The first coat should be cooled before the second is applied; and the second coat should be neither so hot or so prolonged as to soften the first. The coating should be smooth, durable, glossy, hard, tough and perfectly water proof. Samples of the varnish used should be required and analysis of these samples made. Physical tests should also be made with test specimens.

Nothing more seriously affects good service or the pocket of a water company or municipality and yet no element of the work is regarded with such flagrant carelessness.

SCRAPING MAINS.

This method of removing incrustations and deposits has not been largely resorted to in this country up to the present time, although, in England, scrapers for cleaning mains have been in vogue for thirty years. In some places, where the crenothrix is encountered the mains are scraped annually. Spasmodic efforts have been made on this side of the water in past years. Notably at Halifax, St. Johns, Boston, and a few other places in New England.

The list which follows shows the gain in delivery reported at various places in Great Britain and Ireland, as a result of scraping:

Owestry, 54% 6″ main
Lancaster, 56% 8″ main.
Bradford, 55% 18″ main.
Whitelawn, 28% 12″ main.
Waterford, 40% 13″ main.
Cuper Fife, 52% 7″ main.
Merthyr Tydfil 30% 14″ main.
Merthyr Tydfil 82% 12″ main
Omagh, 300% 6″ main.
Lanark, 34% 7″ main.
Bridge of Allen 35% 6″ main.
Thurso 7% 6″ main.
Cowdenheath 23% 6″ main.
Burntisland, 43% 8″ main
Torquay 28% 10″ main.
Aberdeen 107% 4″ main.

The following data relating to scraping operations at Halifax is taken from a paper by E. H. Keating, City Engineer of Water Works, read March 15th, 1882, before A. S. C. E. "The effect of removing the incrustation from the mains was most marked and beneficial upon the water supply of the city as seen by comparing the pressure taken at 25 hydrants on the wharf properties along the harbor in the month of February, 1880, 1881 and 1882.

The average pressure on the 25 hydrants in 1880 34.2 lb. sq. in.

The average pressure on the 25 hydrants in 1881 43.5 lb. sq. in.

The average pressure on the 25 hydrants in 1882 52.4 lb. sq. in.

"If we now turn to the high service probably the best example to take will be the highest part of the city supplied with water. The pressure at the most elevated plug taken at the same time as those previously given follow:

The pressure taken in February 1879, 8 lbs. per sq. in.

The pressure taken in February 1880, 8 lbs. per sq. in.

The pressure taken in February 1881, 28 lbs. per sq. in.

The pressure taken in February 1882, 34 lbs. per sq. in."

Other examples quite as striking could be given

TABLE 4—Standard Sheet Recommended for Reports of Cleaning and Testing Mains, also Showing Results of Cleaning Mains to Date.

Size of Pipe Inch.	Age of Pipe Years	Length of Pipe feet	Approximate Amt. of Corrosion per Lineal foot	Head in feet per 1,000 Before Cleaning	Head in feet per 1,000 After Cleaning	Velocity in ft. per second Before	Velocity in ft. per second After	Observed Discharge Gals. per min. Before	Observed Discharge Gals. per min. After	Value of C in V=C $\sqrt{rs}$. Before	Value of C in V=C $\sqrt{rs}$. After	Calculated Discharge same head clean pipes	VARIOUS CITIES AND TOWNS IN ENGLAND
3	29		28.98	42	47			47	143				
3	29		31.00	54	56			79	188				
	29			70	74			143	200				
	32		63.00	77	82			16	150				
	32			72	72			115	187				
	26		27.00	56	62			35	220				
	26		29.00	36	43			65	130				
4	29		33.33	40	45			69	115				
4	29			38	42			125	107				
6	38			1.30	2.70	0.38	0.76	33.3	66.6	29.5	41.5	170	
				2.50	1.50	0.57	0.95	50.0	83.3	32.2	68.8	125	
				6.90	1 50	0.95	1.13	83.3	100.0	32.3	82.2	125	Boston, Mass., Dexter
				14.40	3.80	1.13	1.51	100.0	133 3	27.1	69.4	205	Brackett
				19.20	4.20	1,32	1.70	116.6	150.0	27.1	74.2	215	Jour., N E W W Asso.
				25.40	6 50	1.51	2.08	133,3	183.3	26.8	73.3	265	V. 13, p 333
				33.80	9.40	1.70	2.46	150.0	216.6	26.1	71.8	320	
10 } 9 } 8 }		73,920	24.00					438	643				Torquay Water Works, Eng
10						2.1	2.6	516	633				
						2.9	3.4	705	835				
6	36	650	16.00	73.6	73.6	4.9	8.6	434	763				N. Y. City, Nat. W M C Co.
				59 8	36.8	1.7	3.8	150	332				Brooklyn, N. Y. " " "
30	14	18,200		253	253	3.74	5.6	8,250	12,350				Atlanta, Ga. " " "
6	30	210				11.5	17.0	1,012	1,500				" " " "
6	30	325				9.8	16.2	862	1,425				" " " "
6	47					3.0	4 25	261	375				Jersey City, N. J. " " "
6								975	1,425				Wilmington , Del. " " "
8	35	1,000						1,050	1,402				Far Rockw'y, N.Y. " " "
6	16	820	44.00	97	97			412	650				Washington, D.C. " " "
48				*b* 1.039	*x* .7115	*b* 3.492	*x* 3.728	19,725	21,037	*a*	*b* 139.9	*c x* 140.1	Boston, Mass
				2.068	1.2206	4.980	4.965	28,160	28,076	108	141.7	142.1	Demond Fitzgerald
		1,747		2.637	1.8485	5.591	6.195	31,613	35.033		143.2	144.1	Trans. A S C E, V 35, p 241
6	72	447		120	46			364	710	47	106		

x. When New.
a. After cleaning 16 years old,
b. Observed average value before cleaning 16 years old.
Nearest velocities and loss of head recorded before cleaning 16 years old

and at several points where the water would not flow from the nozzles there is now a pressure of from 12 to 19 lbs. per sq. in. Mr. Keating reports that the mains were all heavily tuberculated in some instances the incrustation being 1½ inches thick.

Cleaning in this instance was undertaken to prevent costly new construction and was found to be successful. The experience in St. John's was similar. In Boston the pipes cleaned were not the supply mains, but the distributing pipes in the streets, the size being 6 inch and 12 inch diameter. Mr. Dexter Brackett who gives an account of the operations in Boston. (Jour. N. E. W. W. Ass'n Vol. 13, p 333. See Discussion) states, that, "The machine was very successfully used." Referring to the results, Table No. 4, P. No. 336, he says, "It will be noticed that the discharge of 6 inch tuberculated pipes was from 25 per cent. to 35 per cent. of the quantity which a clean coated pipe might be expected to deliver, under the same head, and that the discharging capacity of the pipes was more than doubled by the removal of the tubercles." Recently numerous tests have been made of this process. The results of these tests are also shown in Table No. 4.

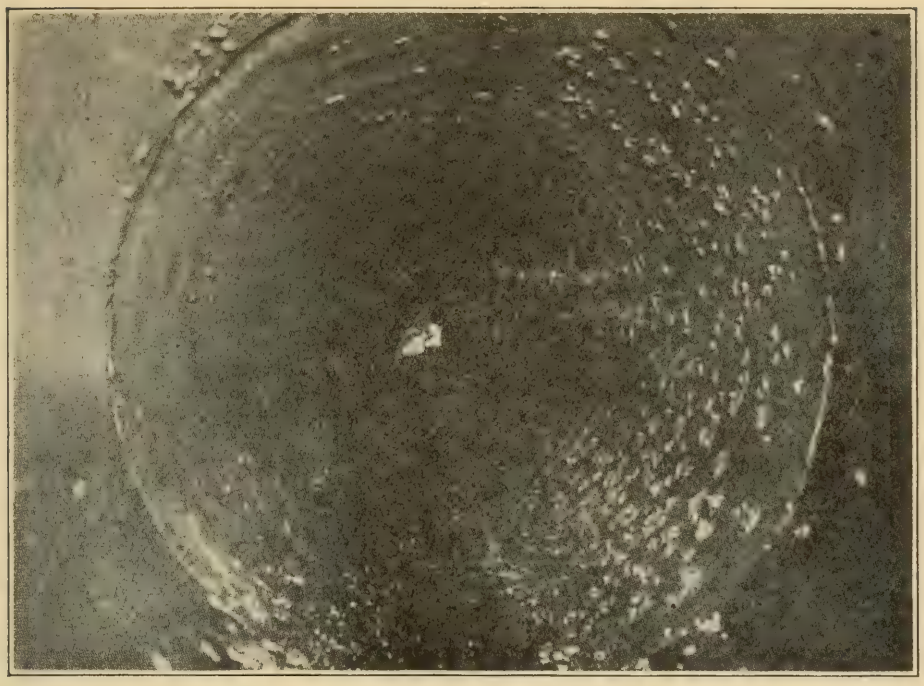
The feasibility of scraping mains to remove incrustation and deposits has been brought to my attention but recently. The need and desirability of some device which could accomplish this has occurred to me frequently, but the opportunity has never before been presented for me to investigate its possibilities. The rust tubercles so often occur separately or in combination with organic growths, that it is possible no treatment of water, of which we now possess knowledge, will obviate an ultimate serious depreciation in the discharge of mains, and hence some process of removal or else reinforcement will have to be resorted to until such time as the interior of all our mains are enameled, or coated by some process which will preclude rust. Besides it is sometimes impractical to use filtration or more expensive than securing a supply from another source. The development of these nodules in small

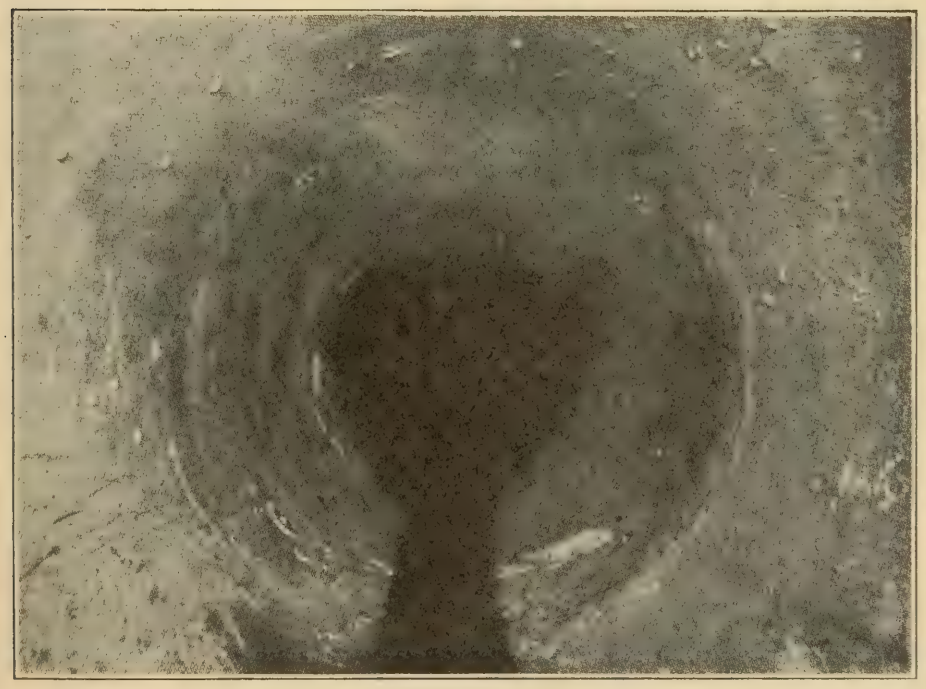
quantities is sufficient to effect a startlingly large reduction in capactiy. Reference to the Photograph below; which is taken from a paper by Mr. Desmond Fitzgerald, (Trans. A. S. C. E. Vol. 35, P. 241); shows the interior of a 48 inch main, which forms a part of the Sudbury Conduit in Boston, after 16 years use. A comparative test on the main before and after cleaning showed an increase of 30 per cent. in capacity. The photograph shows no serious conditions and it is well known the effect of surface roughness is much less in large than small pipes. Mr. Fitzgerald states: "It was found possible to remove tubercles without injuring materially the original coating underneath them and the original condition of the pipe was practically restored." The cleaning in this case was done by hand with old round pointed shovels and wooden scrapers made of oak. Mr. Fitzgerald says "The tubercles generally had central points or very small spots of attachment to the iron pipe. At these points the coating was lacking *of course*; but around them the tubercles spread over the surface of the coating, which remained in fair condition beneath."

I personally inspected the cleaning of a section of 8 inch main at Far Rockaway, N. Y., where subsequent tests made by Mr. Charles R. Bettes, Chief Engineer, showed a gain of 33 per cent. This main I should say would have been considered clean by many. The incrustation was not continuous, was not over one-eighth of an inch to one-fourth of an inch thick and covered a small area of the surface.

EFFECT OF SURFACE ROUGHNESS

Whereas the effects of surface roughness in channels and pipes have long been recognized and attempts have been made, even in some of the earlier formulae, to provide co-efficients adaptable to ever varying conditions, the results so far achieved have at best been approximations. While recognized, these effects in pipes have not been appreciated until very recently.





To verify this statement we have only to review the history of the design of riveted steel and iron pipe lines for a few years past. We find some of our most eminent hydraulicians applying coefficients, in $V=C\sqrt{RS}$ to riveted pipes of the same size and under similar conditions, equal to, if not greater than, the coefficients applied to smooth, coated cast iron mains. We know the loss of head in steel pipe, due to rivets and seam laps is 12 to 40 per cent. of the available head, depending upon the diameter, velocity and plate thickness, and hence the proper coefficients for such pipe are less by 10 per cent. to 28 per cent. than the coefficients applied to smooth cast iron pipes. The effect of plate thickness is nicely demonstrated in the following Table No. 5.

Messrs A Fetley and F. P. Stearns, (A. S. C. E. V. 14, P. 1.), in experiments made upon the Sudbury Conduit, found that when the inside of the brick conduit was lined with a coating of mortar made of pure Portland Cement its flowing capacity was from 7 per cent. to 8 per cent. greater.

Also in a tunnel 4,614 feet in length in which the rock sides had been left ragged for 4,362 feet without lining, but with a smooth concrete floor, the coefficients in the Chezy formula was found about 40 per cent. smaller than for brick conduit, the hydraulic mean depth being the same in both. Darcy found by experiment that the coefficient in clean coated pipes 8 inches dameter, was 16 per cent. larger than in uncoated pipes of the same size. It is highly probable that coating unevenly applied will cause a decrease of 25 per cent. in the discharge of new pipe.

We can more readily appreciate with these facts before us, the enormous decrease in discharge and increase in friction head resulting from deposits and tuberculation of the inner surface of the pipes. The area of cross section and hydraulic mean radius are reduced. The ratio $\frac{a}{p}$ = hydraulic mean radius, decreases directly as the diameter, thus,

area 6 in. pipe = 28.3, circum = 18.86, ratio a to p = 1½—1
" 12 " " = 113.10, " = 37.699, " a to p = 3 —1

Table No. 5

Comparison of Le Conte coefficients for W. I. pipe and coefficients for cast iron pipe. Assume Mr. Le Conte's coefficients are for 3 feet velocity.

	No. 16	No. 14	No. 12	No. 10	No. 9	No. 8	No. 7	No. 6	No. 4	No 1-4"	No. 3	No 3-8"	Cast iron
12 Inch	100	99	97	95	94	93	91	90	88	87	86	78	106
24 Inch	.....	111	109	107	106	104	103	101	98	97	97	87	123
30 Inch	.....	114	112	110	109	108	106	105	102	101	100	91	127
36 Inch	.....	116	114	112	111	110	109	108	105	104	104	95	129
42 Inch	.....	.....	.....	116	115	114	113	111	109	109	108	100	132
44 Inch	.....	.....	.....	120	119	117	116	114	112	111	110	100	133
48 Inch	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	134

The surface exposed to friction is proportional to p. Hence, the effective head per square inch required to overcome friction increases inversely as the diameter. In addition, in a main of given size, a larger surface is exposed to friction. For instance, in a 10 inch main with nodules one-eighth inch to three-eights inch in height, the surface exposed to friction, due to the irregular contour, would be approximately 35 inches whereas, the circumference of the pipe is only 31.4, the increase being about 11 per cent. As the area of cross section is diminished the velocity for the same discharge must be greater. The loss of head increases as the square of the velocity. Add to these the eddies caused by protuberances in the pipe and the concomitant energy expended in impact, caused by the unsteady motion of the particles of water, thus creating additional loss of head, and we see the cumulative effect produced.

The following velocity curves determined by the Pitometer give a graphical illustration of the effect of surface roughness in a 6 inch main in Philadelphia.

TABULATION OF RESULTS.

I feel I have given sufficient evidence that the subject of tuberculation and deposits in pipes is not solely an academic question and of interest only to the biologist and experimenter, but that it has a practical side of vital concern to the water works superintendent. It is my desire to show that it is of paramount importance to standardize the reports of all tests which may be made.

In the discussion which follows this notation will be used:

V=Velocity in feet per second.

D=Diameter of pipe in feet.

$$R = \text{Hydraulic mean radius} = \frac{D}{4} = \frac{\text{area of pipe in sq. ft.}}{\text{circumference in feet}}$$

H=Head of water in feet.

Hf=Friction head in feet.

VELOCITY CURVES

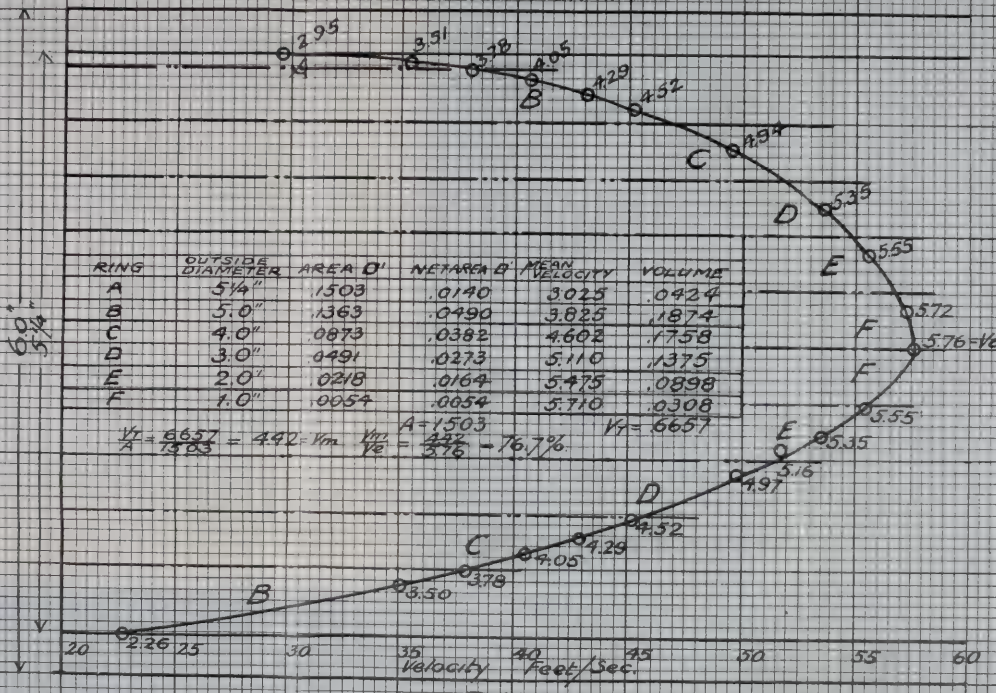
SHOWING

EFFECT OF CLEANING A 6 IN WATER MAIN

BUREAU OF FILTRATION

PHILADELPHIA APRIL 1907

BEFORE CLEANING

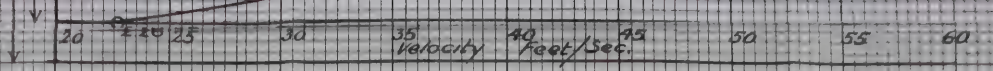


RING	OUTSIDE DIAMETER	AREA O'	NET AREA O'	MEAN VELOCITY	VOLUME
A	5 1/4"	.1503	.0140	3.025	.0424
B	5.0"	.1363	.0490	3.825	.1874
C	4.0"	.0873	.0382	4.602	.1758
D	3.0"	.0491	.0273	5.110	.1375
E	2.0"	.0218	.0164	5.475	.0898
F	1.0"	.0054	.0054	5.710	.0308
				Vf =	.6657

$\frac{Vf}{A} = \frac{.6657}{.1503} = 4.42 = Vm$ $A = .1503$ $\frac{Vm}{Vc} = \frac{4.42}{5.76} = 76.7\%$

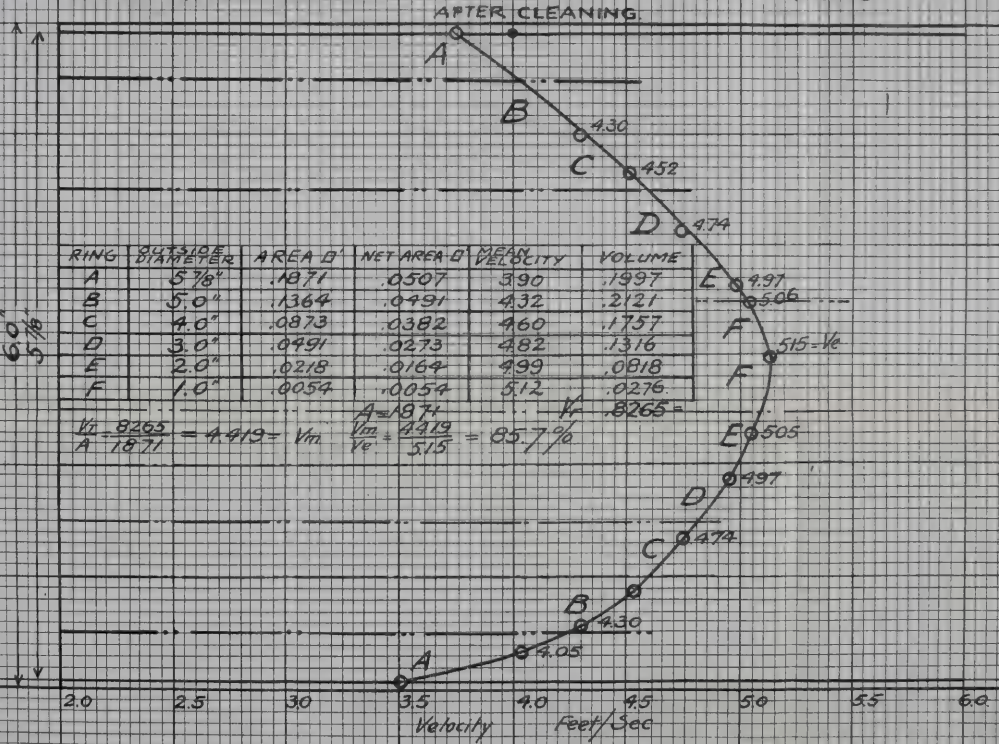
DATA

	BEFORE CLEANING		AFTER CLEANING
DIAMETER	5 1/2"		5 1/8" ⊗
LOSS OF HEAD PER 100' LENGTH	12'		4.6'
AVERAGE VELOCITY MEAN VELOCITY	76%		86%
MEAN VEL. FREE	5.37 FT/SEC.		8.06 FT/SEC.
DISCHARGE 2.5"	364	BY PITOMETER	710
INCREASE		" "	95%
DISCHARGE CU.FT./3 MIN.	2.31	BY TRIDENT METER	4.48
INCREASE		" "	94%



DATA

	BEFORE CLEANING	AFTER CLEANING ⊛
DIAMETER	5½"	5⅞"
LOSS OF HEAD PER 100' LENGTH	12'	4.6'
AVERAGE VELOCITY		
MEAN VELOCITY	76%	86%
MEAN VEL. FREE	5.37 FT/SEC	8.06 FT/SEC.
DISCHARGE 2.5"		
DISCHARGE GALS/MIN.	364 BY PITOMETER	710
INCREASE		95%
DISCHARGE CU.FT/5 MIN	2.31 BY TRIDENT METER	4.48
INCREASE		94%
"C" IN FORMULA V=C√RS	47	106
"n" IN KUTTERS FORMULA	.0171	.0098



RING	OUTSIDE DIAMETER	AREA "a"	NET AREA "a"	MEAN VELOCITY	VOLUME
A	5⅞"	.1871	.0507	3.90	.1997
B	5.0"	.1364	.0491	4.32	.2121
C	4.0"	.0873	.0382	4.60	.1757
D	3.0"	.0491	.0273	4.82	.1316
E	2.0"	.0218	.0164	4.99	.0818
F	1.0"	.0054	.0054	5.12	.0276
		A=.1871		Vm	.8265 =

$\frac{Vm}{A} = \frac{.8265}{.1871} = 4.419 = Vm$ $\quad \frac{Vm}{Ve} = \frac{4.419}{5.15} = 85.7\%$

Note:-

⊛ MAIN LAID IN 1834. LENGTH OF MAIN = 447'
SECTION REMOVED AFTER CLEANING CALIPERED
6.0", THAT AT LOCATION OF PITOMETER 5⅞".
THE FIGURES ABOVE, UNDER "DATA", ARE BASED ON 5⅞" DIAM.

PITOMETER EXPERT

Burt B. Hodgman

L=Length of pipe in feet.

S=Slope of water surface=hydraulic mean gradient $=\frac{H}{L}=$sine of angle of inclination=lost head per foot.

Q=Quantity of water discharged in gallons per minute.

g=Acceleration of gravity=32.194 ft. per sec.

C=A variable coefficient in $V=C\sqrt{R\,S}$

f=Coefficient of friction.

N Kuter's coefficient for roughness of surface.

a=Area of cross section in sq. feet.

p=Circumference in feet—wetted perimeter.

It is now generally recognized that the loss of head caused by the friction in pipes, increases with age, and inversely, the discharge or capacity decreases. Credit must be given to Darcy for first clearly recognizing the three causes of the variation of resistance and more particularly that arising from the condition of the interior surface of a pipe.

These three causes are:

(1) The variation in velocity.

(2) The variation in diameter.

(3) The variation in the roughness of surface, i. e. the physical condition of the interior of the pipe.

Hamilton Smith, (Trans. A. S. C. E. V. 12, p. 119) still further elucidates the above conclusions, as follows:

"The value of C, (coefficient in velocity formula $V=C\sqrt{R\,S}$), varies with,

(1) The character of the interior or wetted surface, being **very low** with **small rough pipes.**

(2) It increases with the velocity with smooth pipes, but **this increase is slight with small rough pipes.**

(3) It increases with the diameter, which is to some extent the sequence of the first proposition."

To this may be added, that in some cases of heavy tuberculation in small pipes the value of C actually di-

minishes as the velocity increases. This fact is nicely demonstrated in Table No. 6, P. 352.

The desirability of a general formula which is conveniently useful without a table of coefficients is unquestioned, but the accomplishment of this object is ephemeral. Nearly every year sees new creations in formulae, each one derived, first—from a pennible fitting of plotted curves to represent as well as they may certain experiments, and second—converting these curves into formulae by mathematical slights of hand. All such formulae are delusive because they only betray a discharge of the pipe or pipes in question, at one certain period of their life; whereas, it is more important to get the discharge of the same pipe or many kinds of pipes, at many periods of their life.

A short study of the existing literature upon the flow of water in pipes indicates that even where the most common forms of expression.

$$H_f = f\frac{L}{R}\frac{V^2}{2g} \quad \text{and}$$

$$V = C\sqrt{R\,S}$$

are used, there is still much difference of opinion as to the proper values to be assigned to the coefficients f and C. This is especially true where the interior surface of the pipe is rough or tuberculated.

Much confusion also exists due to the indiscriminate use of D and R (D=4R in circular pipes running full) in the preceding formulae. They are frequently found written

$$H_f = f\frac{L}{D}\frac{V^2}{2g} \quad \text{and}$$

$$V = C_1\sqrt{D\,S}$$

in which case the numerical value of f must be made four times as large and that of C, one half as large as the values in the preceding formulae.

In most branches of engineering experiment must be the ultimate basis of all formulae, rather than

theory alone, although theory is used to advantage in determining the general form of the formulae. If, however, experimentation is diverted to the development of new formulae, rather than to the determination of the proper coefficient to be used in the application of known formulae, confusion rather than simplification results.

Theoretical hydraulic formulae have been so universally used as a basis for empirical ones that there is danger that many may lose sight of the fact that the latter are not even theoretically correct.

A just appreciation of the empiricism of all formulae for the flow of water in pipes will enable us to see more clearly the advisability of adopting the simplest expression obtainable. Much subsequent labor and confusion can be averted if a standard form is adopted for making tests upon the flow of water in pipes, just as the scales of turbidity, color, smell, and other physical qualities of water supply are reported with uniformity.

Of the numberless formulae so far projected, probably the authors most generally quoted in this country and whose formulae or tables are most generally used, are Chezy, Darcy, Bazin, Lampe, Hamilton Smith, Kutter, Fanning, Merriman, Weston, Coffin, Gould, Williams & Hazen, and Rider.

(1) Chezy. $V=C\sqrt{R\,S}=\sqrt{\frac{2g}{f}}\sqrt{R\,S}=\sqrt{\frac{2g}{f}}\sqrt{\frac{D\times H}{4\times L}}=$

$C(R\,S)^{\frac{1}{2}}$, in which $C=\sqrt{\frac{2g}{f}}$

f=coefficient of friction varying with diameter, velocity and roughness of interior surface.

(2) Darcy. (general) for smooth pipes.

$V=\sqrt{\frac{R\times S\times 2g}{Z}}=\sqrt{\frac{2g}{Z}}\sqrt{R\,S}$, in which

$C=\sqrt{\frac{2g}{Z}}$ and

$$Z = \left(0.004346 + \frac{0.0003992}{D}\right) + \left\{\frac{0.0010182 + \frac{0.000005205}{D^2}}{V}\right\}$$

Z=a coefficient for one category which changes with the velocity and diameter.

(3) Bazin. $A V^2 = R S \therefore V = \frac{1}{\sqrt{A}} \sqrt{R S}$, in which

$$C = \frac{1}{\sqrt{A}} = \frac{1}{\sqrt{a + \frac{b}{R}}}, \text{ or}$$

$$V = \frac{R S}{\sqrt{a + \frac{b}{R}}} = \frac{1}{\sqrt{a + \frac{b}{R}}} \sqrt{R S}, \text{ in which}$$

$$A = a + \frac{b}{R} = 0.00007726 + \frac{0.00000162}{R} \text{ for one}$$

category, viz:—clean cast iron pipe. A=a coefficient which changes with roughness and diameter and is constant with different velocities and degrees of slope.

(4) Lampe. $V^{1.8} = \frac{R^{1.25} S}{K}$, in which K = a coefficient varying with the roughness of interior surface.

For clean cast iron pipe K=.000390 and the formulae becomes, therefore,

$$V = 203.3\ R^{0.694}\ S^{0.555}$$

(5) Kutter. $V = C \sqrt{R S}$, in which

$$C = \frac{\left(41.6 + \frac{1.811}{N} + \frac{0.00281}{S}\right)}{\left(1 + \left(41.6 + \frac{0.00281}{S}\right) \times \frac{N}{V R}\right)}$$

N=coefficient of roughness=0.011 to 0.013, for clean cast iron pipes.

C and N, in the above formulae, vary with the velocity, diameter and roughness of surface.

(6) Hamilton Smith. $V=M\left(\frac{D\ H}{L}\right)^{1/2} = M\ (D\ S)^{1/2} =$

$2\ M\ \sqrt{R\ S}$ in which $C = 2\ M \therefore V = C\ \sqrt{R\ S}$

(7) Weston. $H._f = Z\frac{L\ V^2}{D\ 2g} \therefore V^2 = \frac{2g}{Z}\ \frac{DH}{L}$ &$V=\sqrt{\frac{2g}{Z}}\sqrt{DS}$

$= 2\sqrt{\frac{2g}{Z}}\sqrt{R\ S}$, in which $C=2\sqrt{\frac{2g}{Z}} \therefore V = C\ \sqrt{R\ S}$

(a) $Z=\left\{0.017379+\frac{0.0015965}{D}+\frac{0.00407273+\frac{0.000020816}{D_z}}{V}\right\}$

(b) $Z = \left(0.0198920+\frac{0.00166573}{D}\right)$

With the value (a), of Z, substituted, the formula is the same as the Darcy in (2). The second value, (b), of Z, is another form of the Darcy formula.

Mr. Weston uses (a) for velocities of flow less than 0.33 feet per second and (b), which is generally known as Darcy's formula, for velocities of flow including and above 0.33 feet per second.

(8) Coffin. $V=C\ \sqrt{R\ S}$, as in No. 1.

(9) Gould. $A\ V^2 = \frac{D \times H}{L}$ or $V^2\ 2 = \frac{1}{A} D \times S$,

$\therefore V = \sqrt{\frac{1}{A}}\sqrt{D\ S}$ in which $A = \frac{Z}{2g}$, as found

in No. 7 and $\frac{1}{A} = \frac{2g}{Z}$,

whence $V = \sqrt{\frac{2g}{Z}}\sqrt{D\ S} = 2\sqrt{\frac{2g}{Z}}\sqrt{R\ S}$, in which

$C = 2\sqrt{\frac{2g}{Z}}$ as above.

(10) Fanning. $V=\sqrt{\frac{2g}{m}}\sqrt{R\ S} = C\sqrt{R\ S}$, in which

$C = \sqrt{\frac{2g}{m}}$, and m, coefficient of friction = f as in No 1.

(11) Merriman. $V = V\sqrt{\frac{2gDH}{fL}} = V\sqrt{\frac{2g}{f}}\sqrt{DS} = 2V\sqrt{\frac{2g}{f}}\sqrt{RS}$,

in which $C = 2V\sqrt{\frac{2g}{f}}$, and f = 4 f, in 1, 8 & 10

(12) Williams and Hazen. $V = C R^{0.63} S^{0.54} 0.001^{-0.04}$

in which C is a coefficient, "the value of which is an approximation to a constant, but depends upon the roughness of the pipe and upon the hydraulic radius and slope."

(13) Rider $H_f = 2.073\frac{V^{1.8} \times L}{D^{1.25} \times 5280} = .000392\frac{V^{1.8} L}{D^{1.25}}$, or

$$V^{1.8} = \frac{1}{.000392} D^{1.25} S = 2551 D^{1.25} S$$

$$\therefore V = 201.5 R^{.694} S^{.555}$$

This formula may also be written $V^{1.8} = \frac{R^{1.25} S}{K}$

in which K is a constant coefficient.

Now what do we discover from the above?

That ten of the thirteen formulae tabulated are reducible to the form

$$V = C\sqrt{RS}$$

known commonly as the Chezy formula, and which may be said to be the basis upon which these ten velocity formulae are constructed. The essential difference between them lies in the manner of obtaining a value for the variable coefficient C. Four of the ten, Hamilton Smith, Coffin, Merriman and Fanning, use the simple Chezy form with modifications in the value assigned to their coefficients and the functions included under the radical term.

There are many other formulae which could be mentioned and which are reducible to this form, as for

instance, those of Eytelwein and D'Aubisson, and the formulae of Hawksley, Jackson, Box, Beardmore, Blackwell and others. We may, therefore, infer from its frequent adoption, modification or transportation in the writings of many hydraulicians that the Chezy formula has been generally accepted as one founded upon correct principles.

The three remaining, No. 4 and No. 12 and No. 13 are of the exponential variety, a form of expression which has been advocated, to some extent, as representing more truly the actual velocity and as obviating the necessity of a variable coefficient which implies tabulation. They are unhandy, however, on account of the implied use of logarithms or the slide rule, with which many are unfamiliar. These exponential formulae, as written by Hazen, Prof. Unwin and others, have been reduced to the following form by Mr. W. E. Foss (Jour. Ass'n Eng. Soc., June, 1894.)

$$S = b \frac{V^x}{D^y}$$

The constant exponents and coefficients are truly applicable, however, only within limited ranges of velocities and diameters. This is especially true when the degree of roughness of interior is considered; hence the constant change in the value of the exponents, as well as the coefficient, to suit special conditions or the fancy of some experimenter, makes them difficult of selection and dangerous to apply. Messrs. Williams & Hazen have in their "Hydraulic Tables" used a formula of the exponential class with a constant coefficient, C= 140, for all diameters over 4 inches and for all velocities, but decreasing with various ages of pipe or degrees of interior roughness, so the necessity of a variable coefficient with the concomitant tabulation is still apparent. Moreover, the exercise of discretion in selecting a coefficient for a special case, which a general formula would eliminate, depends more upon the condition of the interior surface than upon the variation in di-

ameter or velocity, as these factors are readily determined.

This is the first case known to the author, where an attempt has been made in this country to tabulate coefficients for varying ages in pipes although Mr. Weston in 1896 (Trans. A. S. C. E. Vol. 35, P. 289) suggested a new variable coefficient for Darcy's formula, Zy = Z+(Z 0.0313 y), y being equal to the number of years of service, by which the number of years a pipe has been in service might be taken into consideration. He also gives a table of multipliers in his "Friction of Water in Pipes," as do Mr. Gould and Mr. Coffin in, "Elements of Water Supply Engineering," and "Graphical Solution of Hydraulic Problems. "So little is known however, of the specific effect of interior roughness that a table at this date which attempts to provide coefficients depending upon the age of pipe is apt to be misleading.

Reference to Table No. 6 shows clearly that the annual reduction is far from constant. The annual reduction in the value of C varies from .92 to 9.7. Another interesting deduction which may be drawn is that the rate of annual depreciation in the discharge is not constant, but seems to diminish somewhat with age. The velocity too, as might be anticipated, also affects the amount of reduction to some extent. The reduction increases, approximately, with the velocity up to 16 inches and apparently decreases as the velocity increases in the larger sizes. Also there seems to be a critical velocity (indicated by brackets) up to which point the value of C increases with the velocity as in clean pipe and then suddenly drops. This critical velocity, if I may use that term, also seems to increase approximately with the diameter of the pipe and is inappreciable in the larger sizes. No definite conclusions can be reached from these observations but careful analysis and a symptomatic treatment of the question would develop much. I hope the waterworks fraternity will take enough interest in this matter to overcome the lack of reliable information.

The authors of the Kutter formula have attempted by the introduction of a "coefficient of roughness," N, into their value of C, to provide a general formula, but in justice to the authors it must be said that their formula was not primarily intended for application to pipes. It was designed for use in open channels where the variation in the character of the wetted surface offers a more serious objection to the tabulation of values for a coefficient than exists with regard to pipes. The Kutter formula may be said to be an attempt to express the value of C in the Chezy formula as a function of three quantities—roughness of interior surface, hydraulic radius (diameter) and slope (velocity). The coefficient N once determined is supposed to be constant, but N varies with the velocity as shown below.

V=	N=
2.30	.0093
4.30	.0101
5.30	.0109

The above was taken from one example (P. 145, "Flow of Water in Rivers and Channels," Ganguillett & Kutter) of a new 6 inch, cast iron pipe. It is seen the coefficient decreases as the velocity increases. In this case a variation in velocity of 3 feet produced a variation in N=.0016.

Again an exceedingly small change in the value of N causes a great difference in the value of C. For example, with a 6″ pipe and S = .001;

with N= 0.011= 0.012= 0.013
C=87.4 =77.5 =64.5,

or a change of .002 in N, produces a change in the estimated discharge of a 6 inch main =39%.

The combination of the two facts cited above is sufficient to show the grievous errors which may result from the use of this formula on the supposition that N is dependent upon roughness alone.

TABLE 6. SELECTED EXPERIMENTS

Aged Pipe– Cast Iron.

Diam	S	V	Actual value of C	Theoretical value of C When new	Age of Pipe Years	Annual Reduction in Value C		
6	.00766	0.80	26	75	13	3.7		
6	.01678	(1.50)	(34)	80	13	3.5		Schluweg Hamburg, heavily incrustaed. (Iben. Druckhohenverlust.
6	.01933	1.70	34	81	13	3.6		
6	.02444	1.90	34	82	13	3 7	899'	
10	.000937	1.14	81.9	95	6	2.2		
10	.001558	1 51	83.3	96	6	2.1		Ehmann Stuttgart. Slight mud deposits, occasionally 0,016 feet deep. Large
10	.002322	(1.90)	(86.7)	98	6	1.9		number of easy curves horizontally.
10	.003719	2 31	83.2	99	6	2.6		Regular grade. Ganguillet and Kutter.
10	.004818	2.68	84.9	101	6	2.7	1,098'	
12	.00041	0.80	81	96	2	7.5		
12	00081	1.20	85	99	2	7.0		Hamburg. Two years old. Slightly
12	.00128	(1 60)	(92)	100	2	4 0		incrustated. (Iben. Druckhohenverlust.)
12	.00299	2.40	86	103	2	8.5	2,149'	
12	.00065	0.90	67	96	15	2.0		
12	.00376	1.80	58	101	15	2.9		Hamburg. Fifteen years old. Rather
12	.00612	(2.30)	(59)	103	15	2.9		heavily incrustated. (Iben. Druckhohen-
12	.00773	2.60	58	104	15	3.0		verlust).
14	.000981	1.51	89.3	104	18	83	1,808'	
14	.001607	1 83	84.5	105	18	1.14		
14	.002280	(2.22)	(86.4)	107	18	1.14		
14	.003600	2.57	79.4	108	18	1.59		
16	.000482	1.15	90.5	107	18	0.92		Compiled from Experiments by F. F. Forbes Jour. N. E. W. W. Assoc. June
16	.000737	1.40	89.5	108	18	1.00		1892. Pipe coated in usual marner. Pipe
16	.001196	1.70	85.2	109	18	1.35		on outside appeared quite bright. Inner
16	.001720	1.97	82.3	110	18	1.58	9,070'	surface ½ covered with nodules a little more than ¼ inch high. Pipe laid with due care,
16	.000459	1.15	93	107	18	0.77		Source of Supply, Charles River,
16	.000713	1.40	90.5	108	18	1.00		through filter gallery on west bank of
16	.001011	(1.70)	(92.5)	109	18	0 94		Charles River, at West Roxbury. Works
16	.001440	1.97	90	110	18	1.15	2,900'	for an additional supply built in 1890-91. consisting of 44, 2½" tubular wells. (Mass. State Board Health 1890-91.
20	.00388	2.71	67.4	117	11	4.5		
20	00455	3.01	69 2	118	11	4 4		Compiled from Experiments Chas. G.
20	.00588	3 61	72.9	120	11	4.3		Darrach at Phila. Pa. 1¼ Bend. Quan-
20	.00722	4.21	76 8	121	11	4 0		tities measured at pump, slip 5%. Trans.
20	.00789	4 51	78.7	122	11	4.0		Am. S. C. E. V. 7, p. 114. Water surface,
20	.00922	5.11	82.4	123	11	3.7	13,350'	from river.
24	.000500	1.57	99.2	118	3	6.3		
24	.000765	1 97	100.6	120	3	6.8		Compiled from experiments of Freeman
24	000988	(2.29)	(103.0)	121	3	6.0		C. Coffin at Taunton, Mass. Pipe coated.
24	.001309	2.55	96.6	122	3	8.4		No branches or services. Jour. N. E. W.
24	.001590	2.91	103.2	123	3	6.2		W. Assoc. Feb. 12th, 1896, quantity measured at pump, slip 5%.
24	.00195	3.32	106.4	123	15	1.1	6,000'	Compiled from experiments at Rochester, N. Y. Geo W. Rafter, Surface water from Hemlock Lake. Trans A. S. C. E. V. 26, p. 14.
30	.00092	1.07	44.7	118	9	8.1		
30	.00131	1.47	51.5	120	9	7.6		
30	.00158	1.75	55.6	121	9	7.2		Compiled from experiments Chas. G.
30	.00184	2.01	59.4	122	9	6 9		Darrach of Phila. Pa., One Curve. Quan-
30	.00210	2.28	63.1	123	9	6.6	30,123'	tities measured at pump, slip 5% Trans. Am, Soc. C. E. Vy. P. 114. Water surface from river.
36	.00093	1.58	59.7	124	7	9.7		
36	.00109	1.74	60.9	125	7	9.1		
36	.00140	2.05	63.2	126	7	8.9		Same as above All curves 25" radius.
36	.00156	2.21	64.6	127	7	8.9		
36	.00172	2.37	66.1	127	7	8 7	4,400'	
							3,700'	

As a matter of fact the value of C derived by any of the foregoing formulae is not adapted to all diameters and velocities to say nothing of the roughness of the interior surface, and, except in the case of the Kutter formula, no attempt is made to encompass the three causes for the variation in the numerical value of C. This fact is clearly shown in the accompanying (Table No. 7), which gives values of C for different diameters derived by formulae and the values of C in the Chezy taken from the Table No. 9, of selected experiments.

TABLE NO. 7.

Comparative values of C. in V.—C, $\sqrt{R. S.}$ when V=3.
New Coated Cast Iron Pipe, well laid.

Author	Diameter of Pipe in Inches											
	3	6	8	10	12	16	20	24	30	36	42	48
Chezy (Selected Exp.)	70	86	93	102	106	114	118	123	125	129	132	134
Darcy General	98	105	107	108	109	110	111	111.5	111.9	112.2	112.5	112.6
Bazin	92	100	110	121	125	130	132	135	137	139	140	141
Kutter N −.013	58	69	75	81	85	92	97	101	106	110	113	116
Kutter N—.311	70	87	94	101	106	114	120	123	128	133	136	140
Hamilton Smith	92	96	99	105	109	114	118	121	125	128	131	134
Weston	100	105	107	108	109	110	111	111.5	111.9	112.2	112.5	112.6
Coffin	97	101	104	105	109	113	118	121	125	128	131	134
Gould	100	105	109	110	110	111.5	111.5	111.5	112	113	113	113
Fanning	97	101	103	105	107	111	114	117	121	125	129	133
Merriman	97	101	103	105	106	109	112	116	120	126	128	131
Hazen & Williams	96	107	109	111	113	116	119	120	122	124	125	128
Rider	98	104	107	110	113	117	120	123	127	130	132	134

Inspection of the table shows that none of the formulae, except the Kutter, appear to be sufficiently flexible to meet the variation in the value of C found in actual experiments, due to the changes in diameter alone, to say nothing of the effects of velocity and roughness.

The maximum variation in the value of "C," from 3 inch to 48 inch, is 70 as shown by the Kutter formula, while the selected experiments give 64, and the next

highest is 49 as shown by the Bazin, which unfortunately gives a discharge which is greater than may be safely expected. Hamilton Smith follows with a total variation of 42, while the range of the lowest is only 14. The lower values of C for small pipes as shown in the selected experiments seem rational and, as these sizes are so very much more seriously affected by deposits and growths, the use of a low coefficient is the height of wisdom.

It is the belief of the author that no rational formula for the flow of water in pipes has yet been devised, which accurately expresses the changes in C for all conditions, and that it is simpler, equally as effective and more accurate to select a value for C, for use in the Chezy formula, from a table, at the outset, to suit a particular condition, than to tabulate values for N or Z or any other coefficient and thus compute the values of C; and that it is just as simple to tabulate values of C in $C\sqrt{RS}$ as for C in $C\ (R^{0.694}\ S^{0.555})$ or any other formula of the exponential type.

None of the formulae submitted are rational, but they are all empirical, viz:—based upon or founded upon experiment. Given V R & S in $V=C\sqrt{RS}$, C may be determined for any particular set of conditions; or having the diameter of pipe (D), head (H), length of pipe, measured on its axis (L), and the quantity discharged (Q), (V=Q÷area of pipe) C can be estimated.

The above refers as well to the determination of f in the formula, for loss of head,

$$H_f = f\,\frac{L}{D}\,\frac{V^2}{2g}$$

These data, or some of them are also necessary to find a value for N, *Z*, A, K, m, or any other coefficient included in any of the formulae submitted. The diameter and length being known, the head and discharge for a given pipe line under certain conditions, may be determined by pressure guages and a meter or pitometer, or when more accurate work is desired peizo-

meters may be substituted for the guages. There may be cases where weir measurement of the discharge is preferable, or the lowering of the water level in reservoirs or stand pipes may be available as a method of measuring the discharge.

The value of V, R, S, and C having been determined they may be tabulated as shown (Table No. 4).

The age of old and tuberculated mains should also be given as well as a glossary of the exact condition of the interior surface. Those who have a decided preference for a particular formula could, from the data thus rendered, determine their pet coefficients ad libitum, and no doubt find fresh and further proof why theirs was the only correct expression.

Without delving further into this question, I hope I have made clear all I wish to show, viz: that it is necessary in selecting any coefficient whether it be C in the Chezy type of formula, Z in the Darcy type, A in the Bazin, or N in the Kutter to choose them with reference to the diameter, velocity, and roughness of interior, and hence it is possible from a proper table of selected experiments to define the value of C to be used under particular conditions with the same accuracy and less trouble than to deduce its value by means of any formula so far derived.

The same discretion has to be used in the selection of N or Z, as C. Is it not better, therefore, with the experimental knowledge which we possess at present, to arrange the results of our experiments in the form of a comparison of the coefficients, obtained in old and tuberculated mains, with the coefficients, deduced from the simple formula $V=C\sqrt{RS}$, for clean pipes, than to attempt special forms of equations?

I have, therefore, tabulated the following data with reference to the basic formula:

$$(1)\quad V=C\sqrt{R\,S}$$

$$(2)\quad H_f=f\frac{L}{R}\frac{V^2}{2g}$$

1st: For the reasons above stated.

2nd: Because, in the absence of a truly satisfactory formula, the form $V=C\sqrt{R\,S}$ has been used in discussing the results of the vast majority of papers found in the Journals of the technical societies, treating of the discharge of pipes under pressure.

3rd: Because of simplicity.

4th: This formula has been used in the design of many important works.

The only defect in these simple formulae is the fact that V cannot be directly computed, but must be obtained by successive approximations, but in no case will more than one or two trials be required to compute the value of V to agree with the corresponding value of C or f.

In considering the effects of tuberculation or incrustation it is generally desirable to know, either, how much the friction head in a given length is increased, or by how much the discharge with a given head has been decreased, as compared with the theoretical loss of head or discharge.

$$Q=a\,V=a\,C\sqrt{R\,S} \quad (3)$$

By reference to table No. 6 it is seen that, owing to the continual change in the character of the interior surface, the value of C is reduced by a certain amount per annum (depending somewhat upon local conditions, methods of coating pipe, etc) and hence a reduction in discharge is equivalent to making a certain reduction in the value of C in equation No. 3. Similarly the increased loss of head is equivalent to making a proportionate increase in the value of f in equation No. 2. Hence, if proper values of C and f could be selected to suit local conditions equations 2 and 3 could be made to express the loss of head of discharge of a pipe of known age and condition.

Unfortunately, the data with regard to these factors in old and corroded mains are so scarce and so little system has been used in reporting the available data that estimates made by use of these or any other formulae are little better than surmises.

If, however, engineers and superintendents would carefully record the interior condition of the pipes under their charge, whenever they break into them, upon a form kept for the purpose, similar to the following: (Form suggested by Mr. Badenhurst, Rochester, N. Y., A. S. C. E. Vol. 36, P. 14. See Discussion).

No.	Diameter of Pipe	Street	Location	Age	Condition
1	4″	Stone St.	Cor. Ely St.	16	Badly corroded. Large tubercles ½″ thick covering surface. Coating destroyed.
2	12″	Genessee	50 ft. South of College	11	Large tubercles ⅜″ thick. Matspongilla. Portion of surface covered = 2-3. Coating dull.
3	10″	Lake Av	At Clay Av	3	Tubercles 1-4″ thick sparse, but of fair size. 25% of surface covered. Coating between tubercles glossy and smooth.
4	16″	Johnson Smith Ave.		10	No tubercles. Slime coating ½″ thick. Mud deposits. Coating good when slime is removed.

If by the use of the pitometer and pressure gauges they would make a *few* tests a year to determine the actual deterioration of their distribution system, recording the result of these investigations on forms similar to those suggested (Table No. 4) and include such data in their Annual report.

If they would give in connection with these data

a full chemical and biological analysis (See tables No. 2 and No. 3) of the water and incrustations together with a description of the source of supply.

We would soon be able to predetermine, with a show of accuracy, the percentage of loss due to the age of our mains, in the same manner as we are now enabled by the aid of table No. 8 to select a proper coefficient C for each diameter of clean pipe with a given or known discharge.

Table No. 8.

Diam Inches	V-1	V-2	V-3	V-4	V-5
3	60	65	70	75	80
6	78	82	86	90	95
8	90	94	97	101	105
10	95	98	102	105	108
12	98	102	106	110	113
16	106	110	114	117	119
20	110	114	118	121	123
24	116	120	123	125	127
30	118	122	125	127	129
36	122	126	129	131	133
42	126	130	132	134	136
48	129	132	134	136	138

This table of proper coefficients was derived by plotting the values of V as derived from Table No. 9 corresponding to the various values of C for each size of pipe included.

I cannot accentuate the value of such data. The expense of deriving them in nominal. If the simple Chezy formula is used as a basis of reporting results their value will be enhanced. This has been shown to be a fundamental equation and is more generally used than any other. Data thus reported may be used as a basis for modifying other formulae. We shall at least have a common medium for the exchange of data, with the form of reports outlined, without need of calling upon an interpreter.

TABLE OF SELECTED EXPERIMENTS. NEW PIPE. CAST IRON.

Table No. 9.

Diam. Inch.	S	V	C	Authority
3	0.00597	1.121	58.01	G. M. Lawford, Curry Rivel Waterworks, 1900-01. Cast iron pipes; asphalted; 1 year in use; clean; slope fairly uniform. Length 5,790 feet.
3	0.01492	1.983	64.93	
3	0.03078	3.080	70.22	
3	0.05361	4.492	77.60	
3	0.05760	4.961	79.88	
4	0.00223	0.928	68.11	G. M. Lawford, as above. Slope irregular with air valves at summits. Length 18,720 ft.
4	0.00377	1.231	68.40	
4	0.00548	1.514	70.83	
4	0.00927	2.015	72.51	
4	0.02629	3.661	78.22	G. M. Lawford, as above. Slope uniform. Length 8,800 feet.
4	0.03043	4.110	81.62	
4	0.04028	4.981	85.97	
4	0.04554	5.490	89.12	
5	0.01436	3.218	83.21	G. M. Lawford, as above. 2 years in use; clean; slope uniform. Length 5,140 feet.
5	0.02086	4.014	86.11	
5	0.02717	4.897	89.96	
5	0.03051	5.131	91.03	
6	0.00459	2.000	83.50	Iben, Hamburg waterworks, 1876. Cast iron pipes; asphalted; new. Length, 1,073. ("Druckhohenverlust.")
6	0.01162	3.300	86.59	
6	0.01621	3.900	86.64	
6	0.02232	4.800	90.87	
6	0.01810	4.700	91.84	E. B. Weston, Prov. R. I., 1876-77. Cast iron pipes; clean; asphalted; 4 years in use. Length 1,171 feet. (Trans. Am. Soc. C. E. V. 22, see No. 4 P. 2.)
6	0.04069	7.250	101.66	
6	0.05591	8.490	103.93	

TABLE NO. 9, Con.

Diam. Inch.	S	V	C	Authority
8	0.00038	0.730	91.75	Ehmaun, Stuttgart. W. W., 1878. Cast iron pipe; asphalted; 4 years in use; clean. Length 810 feet. (Iben, Duckhohenverlust.)
8	0.00085	1.120	94.12	
8	0.00133	1.450	97.41	
8	.0023400	2.05	103.0	Compiled from data derived from test made by F. C. Coffin, eight inch, 10 inch, 12 inch compound main at So. Walpole, Mass. (new). Corrections made to allow for 5-6 per cent. slippage in pumps and actual friction heads. Jour. N. E. W. W. Assoc. Length 8,874 feet. Feb. 12th, 1896.
8	.0050700	3.13	107.5	
8	.0085000	4.08	108.5	
10	.008070	1.32	101.5	
10	.001590	2.00	110.0	Same as above. Length 1735 feet.
10	.002790	2.62	109.0	
12	0.00121	1.568	90.17	Bonn. W. W. 1880. Cast iron pipe; asphalted; new. Length, 17 684. (Iben, "Druckhohenverlust.")
12	0.00195	2.104	95.22	
12	0.00269	2.595	99.84	
12	0.00362	3.096	102.72	
16	0.00059	1.577	110.46	Dr. Lampe, Dantzig. W. W., 1869-71. Cast iron pipe; asphalted; 5 years in use; clean. Length 31,719 feet. (Der Civilingenieur, 1873.)
16	0.00138	2.482	114.19	
16	0.00163	2.709	114.53	

TABLE NO. 9, Con.

Diam. Inch.	S	V	C	Authority
20	0.00012	0.700	99.19	Iben, Hamburg, W. W., 1876. Cast iron; asphalted; new. Length 3,514, feet. ("Druckhohenverlust.")
20	0.00048	1.600	113.36	
20	0.00073	2.000	114.99	C. B. Brush, Hoboken N. J. W. W. 1882. C. I.; coated with tar; 5 years in use; clean. Length 75,000 feet. (Trans. Am. Soc. C. E. V. 19.) (See No. 19, P. 28.)
20	0.00088	2.240	117.48	
21	0.00139	2.957	119.97	C. A. Friend, Seville W. W., 1894. C. I.; Asphalted; 7 years in use; clean; slope fairly uniform. Length 42,050 ft. (Min. Proc. Inst. C. E. Vol. CXIX.)
21	0.00151	3.105	121.26	
24	0.00165	3.590	125.00	W. Hunter, Grand Junction & New River W. W., 1899. C. I.; asphalted; new. Length 38,802 feet. (Lawford.)
30	0.00102	3.080	121.99	C. G. Darrach, Phila. Pa. W. W., 1878. C. I. asphalted; 2 years; clean; Length, 4,000 ft. (Trans. A. S. C. E. Vol. VII) (See No. 52.)
30	0.00108	3.230	124.32	
30	0.00165	4.206	130.97	W. Hunter, Grand Junction & New River, W. W., 1899. Cast iron pipe; asphalted; new. Length, 13,362 feet. (Lawford.)

TABLE NO. 9, Con.

Diam. Inch.	S	V	C	Authority
30	0.00614	8.380	135.31	J. Haynes, Manchester, W. W., 1899. Cast iron; asphalted; new; gradient irreg. Length 22,155 feet. (Lawford.)
36	0.001440	4.225	126.65	Emil Kuichling, Eng. Rec. Mav 2nd, 1896 P. 383. Age of pipe 2 years average of 3 gaugings. 1151 feet long.
48	0.00020	1.908	136.01	A. F. Bruce, Blane Valley Syphon; Glasgow W. W., 1895. Cast iron pipe; asphalted; laid 2 years, in use 2 months. Length 3,557 feet. Min. Proc. Inst. C. E. Vol. CXXIII.) (See No. 53.)
48	0.00071	3.649	137.65	
48	0.00071	3.740	140.17	F. B. Stearns, Rosemary Syphon; Boston, 1879. C. I.; asphalted; new. Length 1,800 feet. (Trans. Am. Soc. C. E. Vol. XIV) (See No. 6. P. 3.)
48	0.00122	4.964	142.12	
48	0.00185	6.194	144.01	
48	0.00071	3.734	139.94	D. Fitzgerald, pipe last described after 14 years service pipe scraped clean and then experimented upon. (Trans. Am. Soc. C. E. Vol XXV See No. 15, P. 10.)
48	0.00122	4.951	141.74	
48	0.00185	6.158	143.16	

ECONOMIC CONSIDERATIONS

It is evident that the incrustations and deposits which form in water mains and are generally classified as tuberculation affect not only the aesthetic value and potableness of a water supply, but also the earning capacity of the plant. I shall not attempt to express the depreciation of a water due to the unsatisfactory physical qualities which may be produced by deposits, and organic growths in pipes. That the physical depreciation of water from any cause can be expressed in dollars and cents is shown in a most interesting way in Mr. Geo. C. Whipple's Monograph, "Value of Pure Water." Communities and water works superintendents are gradually learning this lesson. There is, however, a more practical side to the question if less important from a sanitary standpoint.

It is surprising how little is spent on the upkeep and maintenance of our distribution systems. The following abbreviated table shows, that with the exception of Bay City, where unusual conditions may have existed, the total cost of maintenance of the pipes is less than 2% of the total cost of repairs and less than eight-tenths of one per cent. of the gross revenues.

The places mentioned were picked at random chiefly because they were easily classified by their population. They are representative of "American Practice" in this regard, where a dimunition of pressure or capacity in the distribution and supply mains is universally met with supplementary extensions. There are very many instances where more money spent in maintenance would have saved immediate heavy outlay for new construction, which, if paid for from revenues, forestalled other needed improvements or dividends, and if paid for by bond issues, increased the fixed charges

	Population	Mode of Supply	Cost of Coal Gross Tons	Miles of Main	Gross Rev. from Sale of Water	Maintenance Cost	Total Cost of Repairs to Mains	Cost per Mile	Per Cent. Total Maintenance
Cleveland, Ohio	450,000	Pumping	1.79	607	$841,026	$373,132	$7,059	$11.63	1.9
Lowell, Mass.	100,000	Pumping	4.75	134	214,875	88,357	1,340	10.00	1.5
Brockton, Mass	50,000	Pumping		92	114,289	30,713	304	3.31	.9
Bay City, Mich.	30,000	Pumping	1.98	48	44,770	15,554	1,309	27.27	8.4
Marlboro, Mass	15,000	Pumping	5.09	36	46,100	9,224	94	2.62	1.0

Average cost of repairs to mains 22 cities and towns $9.27 per mile.

of the plant by an amount greater than the proper maintenance costs.

For example: Suppose a 6 inch main to cost $1.00 per foot and to require replacing with another main of the same size in 20 years, owing to increased consumption and the effects of tubercular deposits. Assume money to be worth 4% per annum. Then the cost of a new main at $1.00 per foot, 20 years hence, would be equivalent to 46 cents at the present time. Assume that by proper inspection and cleaning the construction of the additional main could be delayed 10 years. The cost of a new main 30 years hence would be equivalent to 30 cents at the present time, . ˙ . 46—30=16 cents per foot would thus be saved, which at 4%=.64 cents per foot per year. Add to this the saving in interest on $1.00 per foot for 10 years=4 cents per foot per annum, and we have

$$.64 \times 20 = 12.8$$
$$4 \times 10 = 40$$

52.8 cents per foot of 6 inch main as the amount we would be justified in spending in maintenance during 30 years, in addition to the present cost of repairs, which we assume to be the same, and which averages about 17 cents per foot per year for all sizes of mains. In other words, we would be justified in spending just ten times as much for maintenance as we do at present even if all the pipes were only 6 inch. If the periods are reduced to 10 and 20 years respectively, which is more probable with heavy incrustations, then the justifiable expenditure for maintenance would be 48.4 cents per foot for 20 years and 2.42 cents per foot per annum, which would be sufficient to clean the mains once every five years. This estimate refers to the distribution system. Supply mains and force mains from pumping stations would justify a much larger outlay even if the pipe were only of the same size.

This estimate, of course, takes no account of the many other advantages derived, nor of the saving to the

municipality in the cost of tearing up improved streets which can never be properly repaired.

Mr. Desmond Fitzgerald (Trans. A. S. C. E. Vol. 15, P. 337, 1886) makes the following observation: "Great attention is paid by hydraulic engineers to the designing of dams, aqueducts, reservoirs, etc.,—strucures connected with the source of supply; but the question may well be asked: Is proper attention paid to the pipe or distribution system? Experiments and formulae we certainly have on the flow of water through pipes, but the writer is inclined to believe, as a result of observation, that when the water has been once turned into a pipe system, little more attention is paid to the condition of the pipes. Sometimes, it is true, small pipes, fill up entirely, and then specimens are exhibited showing the growth of tuberculation. Again the water becomes bad in one street whilst it is good in the adjoining neighborhood, and the result is attributed to some mysterious agency. It is believed by the writer that one of the great steps in advance that will be made in years to come in the designing of pipe systems will be the introduction of facilities for cleaning out the pipes at stated intervals of time. This will be found necessary, not so much for the purpose of restoring the normal capacity of the pipes as for maintaining the purity of the water."

Although twenty years have elapsed since the delivery of this prediction, and, in the interval, we have arrived at a much keener appreciation of the capacity reduction due to tuberculation, and hence this phase assumes more importance, and although the development of filtration has modified the need of cleaning as a means of purification, it has lost none of its force or virtue.

The author believes it is propitious to suggest, at this time, the advisability of equipping our pipe systems with manholes for the purpose of test, inspection and cleaning. A drawing below exhibits a manhole of this description with hatch box, pitometer, bourdon gauges, and sewer connection. An effective arrangement would

be to tap ordinary 3 inch connections on either side of a gate valve located in these man holes. A small venturi meter could be inserted at any time, in this 3 inch line, by means of flanged connections, and set up in a manhole. By closing the gate between the connection the flow in the pipe could be by passed and measured through the meter and the loss of head in a given section of main obtained by readings from the pressure gauges located in the various manholes. By means of adjustable throat pieces the rate of flow could be adjusted at will.

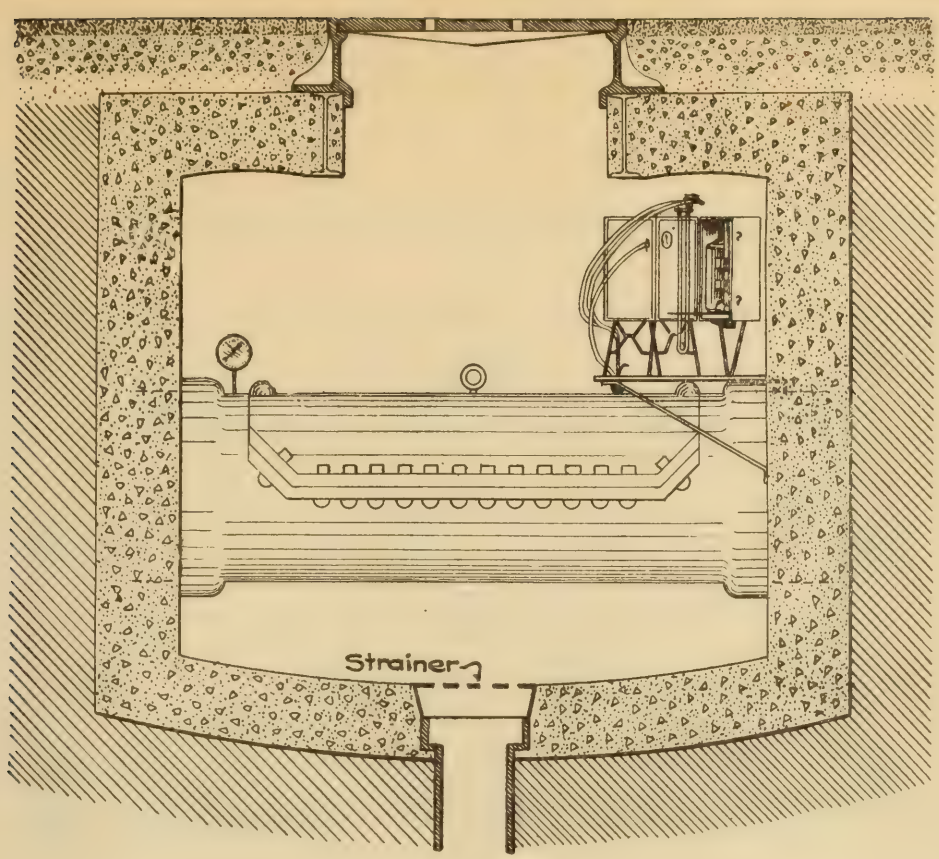
Another arrangement would be to have corporation cocks for the pitometer connections, set in gate boxes, at a proper distance from the hatch boxes, thereby avoiding any possible influence which the eddies caused by change in cross section at the hatch box might produce in the readings.

The valves, too, might be placed in the manholes which would allow of easy inspection and repair. Four way hatch boxes could be built for street intersections. In designing hatch boxes their form should be such as to create as slight a change in cross section as possible. This is not difficult to accomplish. The sewer connection allows any waste water to run off without the necessity of pumping out the manhole and saves injury to pavements. If sewer connections are not available the pressure in the mains can be utilized to operate a water syphon for clearing the manholes. As a matter of fact these manholes would earn a handsome dividend, in the saving they would effect in cost of repairs to street paving, to say nothing of the concomitant convenience in removing obstructions from streets. These manholes not only afford means of inspection of the pipes and facilities for testing to determine the loss of head or the dimunition in flow due to tuberculation, but ready means:—for water waste investigations; for cleaning mains where necessary; for locating leaks; for measuring water used for fires; blowing off and flushing water pipes and sewers; for determining the consumption of different classes of consumers, etc., etc.

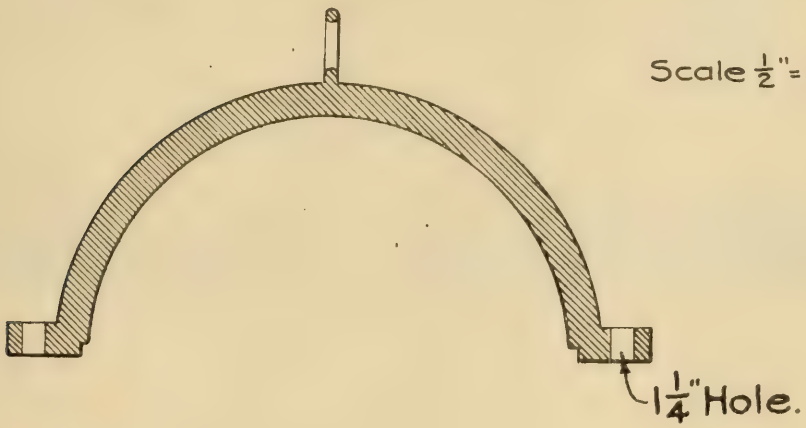
All this can be done and the water works superintendent would be able to remove many problems from the realm of speculative guess-work to the field of definite analysis. Consider the illumination to be derived from such a system on the question of rates alone, which are so vital in their effect upon successful operation. Consider the information which would enable you to state with positiveness the lines or sections needing reinforcement when extensions are planned, as well as the proper size for such lines. Consider the saving due to the reduction of waste. Consider the ease with which your valves could be maintained and shut offs inspected. These and many more advantages can be obtained at relatively low cost.

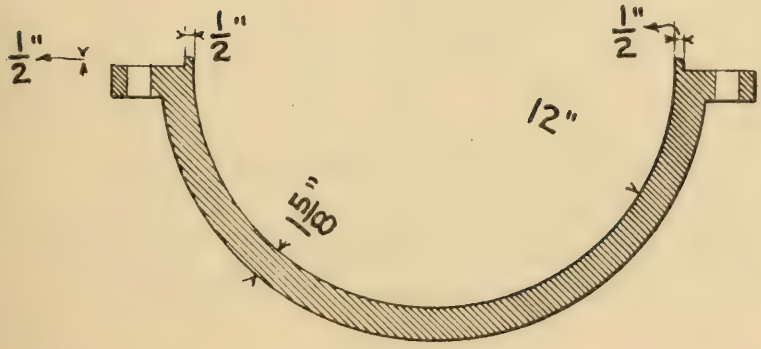
Now what would be the cost of these manholes? For the purpose of estimating I have selected a city of 50,000 population, in which there are 92 miles of mains; size of main, 6—30 inches; net cost of works to date $1,532,500; per capita consumption 60 gallons per day. Supply gravity and pumping. Average size of main equals 12 inches. Estimated cost of distribution system $874,368 or $1.80 per foot. The average size of manhole required would be about 7 feet by 7 feet by 6 feet. Spacing manholes every 1,200 feet at street intersections would require one manhole for each 2000 feet of pipe. The cost of the manholes complete, exclusive of gauges, pitometers or venturi meters, which could be moved from place to place, would be about $300. or 15 cents per foot of main, = $72,864, = 8.3% increase in cost of distribution system = 4.7% increase in total cost of plant. At 5% this would entail an annual cost of interest of $3,643.20. Of course, in large cities and in congested streets where subsurface obstructions are numerous the cost of manholes would be greater, but it is impossible to do more than average results in this paper.

Is there any one present who disbelieves such an outlay would handsomely pay for itself? Is it not surprising that we have gone on and on for years without seriously considering the feasibility of such construction? If there are any who fail



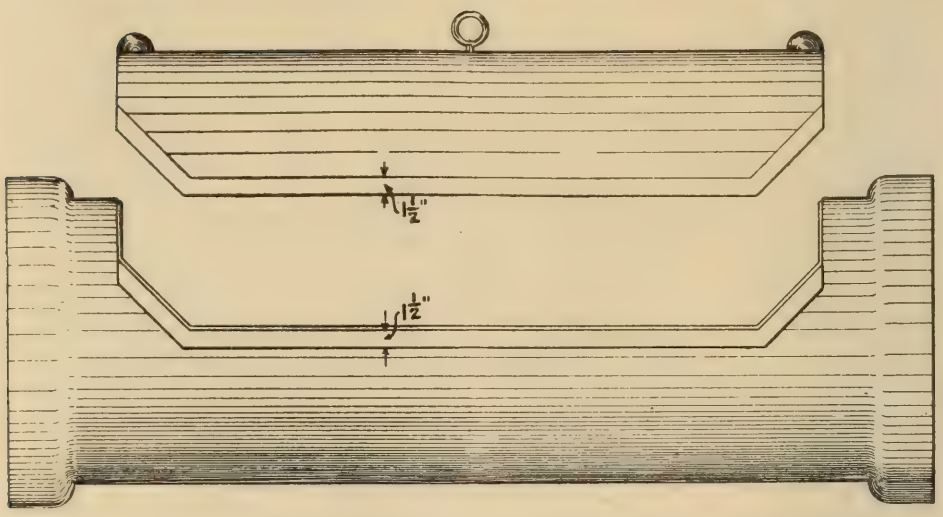
SECTION OF MANHOLE -
showing Hatch Box, Pitometer and Gauge.





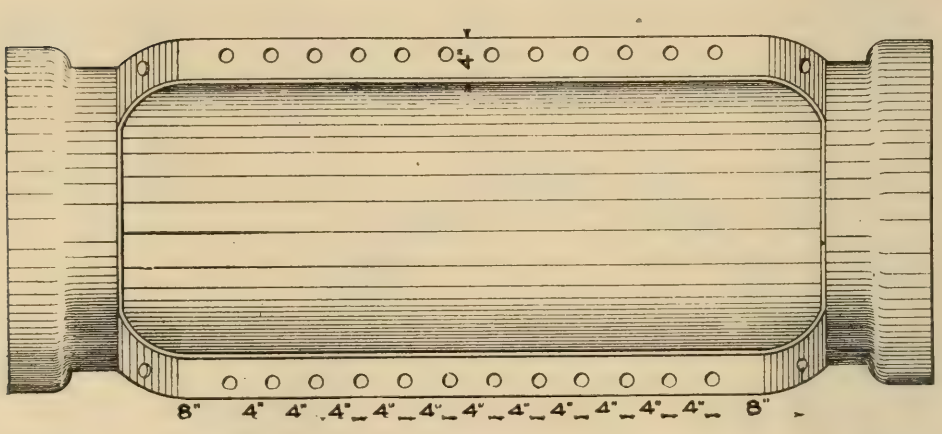
Section A-B.

A



B

Elevation.



Plan.

HATCH BOX.

Scale 1"=1'-0".

PROPOSED MANHOLE

FOR

CLEANING AND INSPECTING MAINS.-

Scale as shown.-May 2, 1907.

to see the ultimate economy or the utility of these manholes, then certainly the advisability of placing hatch boxes at proper intervals and covering them up in the conventional way will not be questioned. The distance between manholes could be lengthened. By intelligent subdivision of a city into districts and the location of manholes on supply or trunk lines, or at critical points, much information would be derived, and the total cost lessened.

Let us now turn to the effect of tuberculation and deposits upon the cost of pumping. We will take the Atlanta 30 inch force main as an example. (See Table No. 4, P. No. 336). The length of this main is 18,200 feet. In this instance it required the same head to pump 8,250 gallons per minute before cleaning, as to pump 12,350 per minute after cleaning. If we assume the loss of head due to friction in the tuberculated main for a discharge of 8,250 gallons per minute equal to the theoretical loss in a clean pipe due to a discharge of 12,350 gallons per minute = 4 feet per 1,000, the total loss of head for the entire length of main $= 18.2 \times 4 = 72.8$ feet . ' .

$$\left(\frac{12,350}{8,250}\right)^2 \times 72.8 = 163.8$$

the loss of head due to friction which would have occurred in delivering 12,350 gallons per minute through the tuberculated main. Also the dynamic head would have been (163.8—72. = 91.0) 253+91=344 feet instead of 253 feet when delivering 12,350 gallons per minute. The P. H. P. required to deliver this amount against 253 feet equals 788 and against 344 feet equals 1072 . . $\frac{1072}{788} \times 100 = 36\%$ more fuel is required to pump 12,350 gallons per minute, through the tuberculated main than one which is clean. It is simple to reduce these figures to dollars and cents for special cases.

The question of deposits in mains seriously affects the estimates of the per capita consumption based on infrequent gaugings or a single gauging made when a conduit or pipe line is new. There has been some dis-

cussion and much divergence of opinion with regard to the effect of tuberculous growths in the old hemlock Lake Conduit at Rochester, but in view of many data supplied since 1892 concerning the retardation effected by these growths, and the annual depreciation in discharge shown by both the Rochester conduits since 1892, it is fair to assume these deposits did materially affect the delivery of the old conduit. This case serves my purpose as a concrete example. Gaugings were made upon the old conduit in 1876, when new, and it was stated the conduit had a capacity of 9,000,000 gallons per day. In the summer of 1890 a water famine threatened and during all the discussion of the question this original estimate of delivery was used as a basis for estimates of the per capita consumption until Mr.

Geo. W. Rafter (Trans. A. S. C. E. Vol. 26, P. 14) found by experiment the conduit was delivering only 7,142,000 gallons per day or a reduction of 21% in 14 years. Subsequent gaugings on the old and new conduits show a steady decrease in delivery as the following table of the delivery of the old conduit from Hemlock Lake to Rush Reservoir shows:

Date	Duration of Experiment hours	Computed discharge in gallons per day of 24 hours
1876 (new)	12 1-2—41 1-2	9,000,000
Oct. 10th, 1890	8	7,185,000
March 22nd, 1891	5½	7,142,000
April 19th, 1892	8	6,753,500
September 24th, 1892	10½	6,805,600
May 5th, 1893	6¼	6,900,300
June 1st, 1894	7½	6,807,400
October 18th, 1895	7¼	6,660,000

There is one point this table fails to develop—that the reduction in delivery commences in many cases very soon after a pipe line is put in service. Sometimes this reduction is noticeable in one or two years.

Estimates of consumption based upon the plunger displacement of pumps may be greatly in excess of the actual use of water. This question was discussed by Mr. Holmes in a paper "Pump Slippage" presented to this association at the last convention. The author had an experience with the engines at the 179th street pumping station, when Chief Engineer of the New York Water Department, a test showed 60% to 65% slip. He has in many other instances encountered slippage from 15% to 30%. The arbitrary assumption of 5% or 10% slip is misleading and frequently inaccurate. An equipment of the kind outlined herein would enable frequent tests to be made to determine the exact slippage and save many dollars in coal bills.

The valuation of a water works plant is modified by the condition of the mains. In some cases where certain rules are applied to hard waters this modifica-

tion may cause an excessive reduction. On the other hand the same formula may be inapplicable to waters conducive to heavy deposits. Thus still another argument is added to show how essential proper inspection is to the whole range of problems presented in the distribution of water in cities and towns.

Of course, it is impossible in a paper of this kind to be specific, but the author believes he has shown that provision for proper inspection is within the means of the average water works and probably economical. Hence, the other multitudinous advantages, effected from an aesthetic or theoretical standpoint, may be regarded as premiums obtained without cost.

I sincerely trust the paper has focussed attention on the possibilities of development in the matter of distribution.

Not being a biologist, but an engineer, I beg of those learned in the ways of bugs, to overlook the crudities which may be apparent in the section of this paper which attempts to deal with them. I also want to assure each and every one that I have no hard feelings for anyone with a formula.

I wish in closing to thank Dr. George F. Whitney for supplying me with many data, as well as Dr. J. Lainson Wills, of New York, for much information in regard to the formation of rust and the variable effects of different water upon iron. To Mr. Burt G. Hodgman I am indebted for reports of tests made in Philadelphia.

CLEANING WATER MAINS.

Park Woodward.

The question of cleaning water mains is one that should interest Water Works management generally. When a Water Works System is first put in operation the piping system is too often put in to meet the contemplated consumption with little or no provision for the future growth of the town or city. This mistake is frequently made, especially when the system is owned and operated by a Municipality, when first cost only is mainly considered. The consequence of this policy results very often in the system becoming inadequate in a few years for the demand upon it. If the rapid growth of the City brings about a greater demand upon the system than was contemplated, the only remedy is to take up the smaller mains and lay larger ones, but it more frequently occurs that the mains become clogged with mud or a tubercular formation, which reduces their carrying capacity materially, and results in loss of head by friction. In a system where the mains are of sufficient size to furnish the volume of water needed, it is much cheaper to have them cleaned out than to take them up and lay larger mains.

In Atlanta we have suffered for years with a tubercular growth in our pipe, which has resulted in reducing the carrying capacity of our system to such an extent that the pressure on our pumps had to be increased to enable us to overcome friction, and supply the system with sufficient water for domestic and fire service and give necessary pressure. To relieve the situation, the question of taking up all of the small pipe in the congested and business parts of the City, and replacing them with larger pipe, has been under discussion for several years. Last year this question became so urgent, that the Water Board called the attention of the City Council to the matter, and put them on notice, that the 30" Main which delivers the water into the reservoir or settling basin was in such a con-

dition that it could not deliver a sufficient amount of water to keep it supplied, the pumps at No. 2 station taking it out faster than it could be delivered and that an additional main had to be laid. This question was up before the City Council, when a proposition was made to clean out this main, restoring it to its original condition. The City Council appointed a committee to investigate this matter, and on March 28th and 29th, two sections of 6″ pipe were cleaned out to demonstrate what could be done. A cut was made on a 6″ pipe connected with a 20″ main under 53 lbs. pressure 220 feet from main. A 6″ meter was put on this pipe and water turned on. The meter after running two minutes register 270 cubic feet. After pipe was cleaned the meter was again put on and run two minutes, registering 400 cubic feet, showing an increase of 130 cubic feet or 978 gallons in two minutes, being an increase of 48.1%. A second test was made with another 6″ pipe, 250 feet in length under similar conditions, and the meter registered 230 cubic feet in two minutes, and after cleaning registered 380 cubic feet, showing an increase of 150 cubic feet in two minutes or 1125 gallons being 65.2%. The committee being satisfied, awarded contract to clean out 30″ main. Before this main was cleaned, the 18,000,000 gallon pump, which delivers the water into the reservoir was put under a pressure of 110 pounds, and made 11 revolutions per minute, delivering 11,880,000 gallons. After cleaning under the same pressure, it made 16½ revolutions per minute, delivering 17,820,000 gallons, showing an increase in delivering capacity of 5,400,000 gallons in 24 hours or 45.4 per cent. This enabled the Department to fill the reservoir, and saved the expense of laying an additional 30″ main (18,000 feet) at that time. The great success obtained here has resulted in the question being under discussion of having all of our mains cleaned out this summer. There is no question but what it will result in giving us a much better supply in many sections of the City where the pipe is reduced in size by reason of the tubercular growth in them.

DISCUSSION.

Jointly on papers by Messrs Hill and Woodward.

Dr. Geo. F. Whitney: I feel a natural hesitancy and reluctance in entering into a discussion which has been handled in such a technical and thorough manner as the tuberculation of cast iron water mains has been discussed here, but I believe that the practical and commercial side of it, which comes under my direct observation in the everyday intercourse of my business, will be of interest to the members of this Association, and I will take the liberty of giving a few of the practical experiences which I have had in the cleaning of cast iron water mains, and will also subject myself to cross-examination by any members of the Association who are interested in this field of work.

Water mains varying in size from 4 inch to 30 inch in diameter have been cleaned, and there has not been a single result that was not in every particular most satisfactory.

There are a number of gentlemen here at this Convention who have had experience in the cleaning of water mains, and I am quite sure that each and every one of them will be glad to corroborate the statements which I may make in regard to the efficiency and value of the method of cleaning cast iron water mains of the tuberculous deposits which accumulate in them.

One of the first experiences was in the City of Reading, Pa., on a 16-inch water main, and in that particular instance it gave them an increase of 14¾ lbs to the square inch, which relieved the very pressing condition at that time which would have necessitated the laying of a parallel line in order to have sufficient water to deliver to the section of the City which was fed by this 16-inch main.

Mr. Neubling, Chief Engineer of the Water Department of the City of Reading, at the time the test was made there, said he would be entirely satisfied if it gave them an increase of 8 lbs. pressure, so you can readily appreciate that he was more than satisfied when he got an increase of 14¾ lbs.

In Jersey City considerable work has been done, confined, however, to 6-inch pipe, but the results have been most gratifying, not only in the percentage increase of water passing through the pipes, but also the actual results attained in localities where they have cleaned pipe (many of which are tenement house districts) and before cleaning the tenants were unable to get water above the second and third floors, whereas, after cleaning the water could flow freely from the faucet on the fifth floor.

This was a condition also observed in Wilmington, Del., where the water department were contemplating putting in a pump to deliver water to the top floor of the Equitable Building, whereas, after they cleaned an 8-inch pipe running down Ninth St., they were able to get water without any assistance on the top floor of that high building.

They have operated in Pittsburg, Pa., on an 8-inch pipe and it has given them an increase of flow through the pipe of 121 per cent., and in Wheeling, West Va., on a 6-inch pipe it gave them an increase of 178 per cent, whereas, in Camden, N. J., it gave them 177 per cent. increase in a 4-inch pipe.

A very interesting demonstration of the method of cleaning water mains was given in the City of Philadelphia, Pa., under Major Gilette , the former Chief Engineer of that city, where very elaborate pitometer tests were made, showing that it gave them an increase of 95 per cent.

Another interesting feature in connection with this test is that you will see that before cleaning the interior of the pipe had a roughness equal to an open stream, whereas, after cleaning the roughness was entirely eliminated, and the pipe showed a surface as smooth as newly laid cast iron pipe.

A very interesting and important feature of cleaning cast iron water mains, aside from the great saving which, of course, you all appreciate, is the increased fire protection. We will take, for instance, the demonstration made in New York City, on 20th Street, under Mr. I. M. De Varona, where it gave them an increase of 76 per cent., or, in other words, before the pipe was cleaned there were 58 cubic feet of water passing through the pipe in one minute,

and after the pipe had been cleaned it showed 102 cubic feet passing through in one minute, or a gain of 44 cubic feet in one minute, and this means that in the event of a fire they would be able to get 330 gallons more of water every minute than they could have gotten through the same pipe before it was cleaned.

This pipe was not particularly a bad one, yet the enormous advantage attained in fighting fires is apparent to everyone, and one which I do not believe that any Water Department can conscientiously disregard.

In Wilmington, Delaware, a very interesting fact was established in connection with this work, and that is that it does not depend so much upon the reduction of the diameter in the pipe, as it does in the roughness of the interior which increases the friction to such an extent that the pressure and flow is very materially affected.

To prove that it is the roughness, rather than the reduction in the diameter of the pipe, I will use this illustration:

At Wilmington, Delaware, where the deposit did not amount to more than ⅛ of an inch, they got an increase of 46 per cent., whereas, in the Borough of Brooklyn, where a 6-inch pipe was reduced to 2 inches in diameter the increase was only 121 per cent., and I think this demonstrates beyond the question of a doubt that the increased volume depends upon the roughness rather than the reduction in the diameter of the pipe, for, if the same ratio of increase was kept up where a 6-inch pipe is reduced to 2 inches that was attained in an 8-inch that had only ⅛ of an inch deposit, it would run up to several hundred per cent., of increase.

Now, of course, one of the most, if not the very most important feature in connection with this work to be considered by water departments, is the great saving, and there are two features of this to be considered. First, the relative cost of laying new mains to get the service, and the cost of cleaning out the mains to get the same service. There is

hardly any city in this country where it will cost less than 85 c. a running foot to lay 6-inch mains, and that is only in Southern states, where the pipes are laid about 12 inches under ground, and in other sections of the country it runs as high as $1.25.

The cost of cleaning 6-inch pipe at the maximum is only 26c. a foot, and where the quantity of pipe is large it brings it down to 19c. a foot, which, compared to the original cost of laying new pipe is a very great saving to the city.

Another point is the saving in the amount of fuel which is consumed in pumping, for where the pipes are tuberculated, the pumps have to operate at a very much higher pressure than where they are clean, which is more than illustrated by the experience in Atlanta, where, with a 110 lb. water pressure before cleaning the pipe, practically 11,000,000 gallons of water was pumped in 24 hours, whereas, after cleaning it, at the same pressure, there were 17,000,000 gallons pumped in 24 hours, with no greater cost of fuel, and I think that it will be borne out by the careful and close observer that there is a saving of just about 36 per cent. in the amount of fuel required before and after the pipes have been cleaned.

The nature of the deposits that have been cleaned from water mains is varied somewhat, but not so much as I think most water engineers have supposed. Of course, it varies in the degree of hardness, but all of it is hard and can not be flushed out, but it requires a mechanical device to remove it.

Another point which interests all Superintendents and Engineers, and one which they are always skeptical about, is the disturbance which the device is to the taps, either driven or screwed, and I am very glad that we have here to-day Mr. Robert Hollingsworth, of Camden, N. J., who observed the influence of the machine on taps when operating in his city, and as the machine passed over these particu-

lar taps they were not disturbed at all. When operating in his city, it was necessary to have a number of holes open and taps exposed, and Mr. Hollingsworth got into one of these holes and held his hand on a driven tap while the machine passed through that part of the pipe, and the tap was in no way disturbed.

MR. LEISEN: The last speaker, Dr. Whitney, referred to the cleaning of a water main at Wilmington, Del. I think it may be of interest to give some details of the work done in that city. The main which was cleaned had originally been put in on the low service system, and when the high service was extended, this main was used for that service. This 8-inch main was the only connection between the high service in the Western part of the cty and that portion feeding down into the business section. We had quite a number of complaints from some of the occupants of high buildings of lack of pressure; in fact, we could not get water to the upper stories except at night time. We determined to make the experiment of cleaning the main out, and see if any relief could be obtained in that way. While I have none of the figures with me, I think the increase of flow was about 50 per cent. We took the increase in flow, and the pressure on the pipe, putting a meter on the line in order to determine just what the increased flow would be, and obtained in that instance very close to 50 per cent. Since then we have extended that service considerably, and the pressure has decreased again and will continue to do so for the next few months until we get our newer service in operation. But the results have been very satisfactory, and we have had no further serious trouble.

MR. COLLINS: I will ask Mr. Whitney if in his experience in cleaning he has run across any other material?

DR. WHITNEY: We have frequently encountered crenothrix. In Far Rockaway there was a piece of lead in the pipe which ran along the bottom on the pipe, and as the machine came along it rolled it up into a ball and stopped the machine. In Pittsburg, when cleaning pipe, the machine was stopped by a lump of lead which weighed 45 pounds (I was anxious to get that piece of lead and bring it to the convention, but the department at Pittsburg seemed to feel

as if they would like to keep it there). In Wheeling, the machine was stopped by a cobble stone, and in another instance by a lump of coal, while in Jersey City, on one occasion the machine brought forth an old umbrella.

MR. SCHWERTFEGER: I am able to corroborate what Mr. Whitney has stated in reference to the large piece of lead which was taken from the 8-inch main cleaned in the City of Pittsburg.

The first 710 feet of 6-inch pipe cleaned by us, we measured with a meter before and after cleaning. Before cleaning, the meter registered 1,600 gallons in five minutes, and after cleaning it registered 4,450 gallons in five minutes, showing an increase of 178%.

This, I believe, is the largest increase that has ever been demonstrated by cleaning pipe so far as is known.

We have samples of pipe that have been taken out after the cleaning process and we find that they are thoroughly cleaned and restored to their original dimensions.

In our second cleaning we drew out from the interior of the pipe an obstruction in the shape of a piece of wood about the size of a base ball bat, which by some means or other had gotten into the main.

We feel so well satisfied with the results obtained by the cleaning operation, that we expect to follow it up and have a great deal of work done, and we have already contracted for over 20,000 feet, and we feel that we are doing very excellent service to the city by having these mains cleaned.

We had intended laying new mains in this particular part of the city, but the results of the cleaning have been so marked, that we now hope and expect to do away with the laying of new mains in this particular territory.

We have inquiries and requests from all sections of the city, wanting the mains along their respective streets cleaned.

MR. REIMER: Mr. Leisen's remarks brought up a question in my mind as to the permancy of cleaning; that is, if the main is cleaned in the summer time or any part of the year, how long will that particular cleaning retain

the efficiency of the flow? Is there any data any one can furnish on that.

MR. LEISEN: As far as our experience is concerned, there was no change whatever in the flow or pressure up to the time that we took another 8-inch lead off of this 8-inch main; then, naturally, the pressure was somewhat reduced. I do not think there was any diminution in the flow subsequent to cleaning due to roughness of the pipe. We have not opened the pipe since, but have no reason to believe there is any further deterioration except what would naturally take place in the course of time. Reduction in pressure was due to the fact that we are drawing off from that main more than its normal capacity.

DR. WHITNEY: The question of cleaning pipe is comparatively new, although there have been a number of devices made for the purpose, but none until the present time have proven to be satisfactory on account of the time required for the cleaning and the inefficiency of the method employed. Abroad it has been done for a great many years and they laid their pipe with the idea of cleaning them at stated intervals.

In Tamaqua the pipe was cleaned as long as 15 years ago by a device which was rather crude in its construction, yet that pipe has not corroded any more rapidly than new pipe which was laid at the same time. This is the only information that I can give you in regard to the tuberculous formation on pipe which at one time had been cleaned by a mechanical device.

A MEMBER: I will ask Dr. Whitney what the chances are of cutting off the services? Take a street say of 5,000 feet long with ten or twenty services running off in grid-iron fashion, how long would it take to clean that main; how long would you have the water shut off?

DR. WHITNEY: The water is shut off for a maximum of about four hours from the time the cleaning begins until all the connections are restored. Of course, if an obstacle is struck in the pipe, such as is frequently done in the way of lumps of lead, sticks, stones, or in one instance an um-

brella, this, of course, would lengthen the time that the water is shut off, because it necessitates digging another hole to remove the obstruction.

MR. DIVEN: I would ask if the Hatch Box spoken of and shown in the drawing is a design, or suggestion, or something that has been in practical use.

MR. N. S. HILL: The drawings submitted in the paper are not intended as working drawings, but rather to indicate what may be done. I may say, however, in answer to Mr. Diven's question that the Hatch Box represented has been practically used in several places.

MR. DIVEN: I do not clearly understand how the number of "hatch-boxes" mentioned in the paper would cover the lengths of pipe stated, and would like to have Mr. Hill explain this more fully. And would suggest that he include in the drawings to be printed with the final proceedings one showing the location of the hatch boxes on a distribution system; something in the form of a map of an imaginary distribution system, with the hatch boxes properly located to cover all parts of the system.

MR. N. S. HILL: My idea is that the process of introducing manholes would be similar to the process of introducing meters. It would be impracticable to start in and place man-holes wherever necessary at once. Probably such a proposition would receive poor support from the average board of water commissioners, or from the committees in council; but I think if the superintendent of the water department would spend a certain small sum each year in locating the man-holes he could very soon have his system sufficiently covered to carry on any ordinary test. My idea in locating these man-holes would be to follow the chief lines of distribution first; for instance, if I had pumping stations on the system I should take the force mains, and then make the man-holes serve as many feet as possible. I do not think it would be possible to lay down any hard and fast rule as to the exact locations of these man-holes; nor do I think it would be advisable to require that man-holes should be placed every 1,000 ft. or every 1,200 ft. or 1,500. I think local conditions should largely govern;

but the matter of locating the man-holes is one of convenience and would be equally as simple as the location of gate valves at proper intervals, or the location of other appurtenances which are now used in the distribution systems.

SECY. DIVEN: Mr. Hill asks us a pertinent question. He says, "What is tuberculation?" When he read that I wondered if Mr. Hill had ever heard of what General Sherman said about war? Speaking of the effect of carbonic acid—carbon dioxide—on pipe, how about an excessive amount of dissolved oxygen in the water, is the effect very much the same?

MR. HILL: The theories in regard to rust in iron differ greatly. One authority claims that carbonic acid is necessary to produce rust. Another claims that oxidation is due simply to the effect of oxygen, and that carbonic acid is not a necessary element to the process of oxidation. I do not think the question has ever been settled satisfactorily to everybody. I referred to a paper by Prof. Walker, of the Massachusetts Institute of Technology, in which he brings out this point very clearly and cites a great many different opinions as to how far carbonic acid gas is necessary to produce oxidation of iron. I cannot pose as a chemist, but I do not think this question has been settled up to the present time.

Prof. Walker thinks that oxidation, or corrosion of iron, is directly proportionable to the oxygen present and is not governed by the carbonic acid gas present in the water. Others hold an opinion directly the reverse.

A MEMBER: Will the deposit on the surface of the pipe take place more rapidly in case of a coated, or uncoated pipe?

DR. WHITNEY: I cannot say whether tuberculation forms more rapidly on coated or uncoated mains. I am not sufficiently posted. There are opinions, however, on both sides, and I have seen some of the best engineers in the country who say that they did not believe it formed any quicker on uncoated mains.

On all coated mains the tuberculous deposit forms practically from a pin point head in the coating and in

removing it by the cleaning process the coating is not injured or removed except at this pin point of formation.

MR. FRENCH: I would like to ask if the cleaner in passing through the pipe in any way damages or injures the house connections, or the corporation taps, or if it in any way obstructs them so that water does not pass through them freely?

I would like to inquire also if in any line you were cleaning where there might be one or two gates within the distance to be cleaned, if there is any danger of the seat rings of the valves being damaged by the cleaner passing through them?

DR. WHITNEY: The taps are occasionally stopped up where the residents do not take the precaution to keep the house faucets closed during the process of cleaning. If, however, the house faucets are kept closed in the residences the service cocks will not be clogged up with dirt. This stoppage of service cocks only happens occasionally and is always due to the disregard of the warning to keep the house faucets closed.

In regard to the pipe cleaning device passing through gates it never damages the gate seats for the reason that the gate is always a little larger than the size of the pipe that it is operating on, and the machine being made of the specific size of pipe being cleaned, the springs are not forced against the gate seats as the machine passes through. We have several times had occasion to take up gates after the machine has passed through them and in no instance have we found the gate seats in the slightest way injured.

The resistance that we have to overcome in cleaning ordinary tuberculated cast iron 6-inch pipe is about 2½ tons. We do not use a cable on any size pipe over 12 inches, as we have sufficient water pressure to produce the motive power.

MR. RAPP: I have had occasion to clean gate-valve seats. I found the valves on a 30-inch main perfectly tight and there was no leak in them. That pipe was cleaned in April, last year. I have not observed that there has been any greater deposit formed since then than would be the case with new pipe.

MR. FRENCH: How long had that 30-inch main been in use that was referred to in Mr. Woodward's paper?

MR. RAPP: Since 1892. I would like to ask Mr. Hill, why is it that this scale forms in a city using filtered water? The water is perfectly clear, no discoloration to it, apparently no solid matter, yet the formation occurs just the same after the water is filtered as it does in the case of muddy river water.

MR. N. S. HILL: I have not gotten down to a point where I feel entirely safe in answering any question about rust on iron; but the tuberculation which occurred in Atlanta was entirely a form of iron rust. I tried to bring out in my paper the fact that there was a form of iron rust which filtration did not eradicate. Our experiments have shown that even with distilled water you get the same rust. Of course, the more nearly pure the water is the more slowly rust forms; in other words, where there are acids present in the water the amount of rust is increased, and filtration will probably retard the rust, but I do not think that you can assume that filtering the water will remove rust or remove the cause of rust, and this is a very, very important point. The filters will remove biological organisms, and remove deposits caused by them, but will not remove the rust.

MR. REIMER: In artesian wells the water is perfectly clear, and yet the tuberculation in artesian tubes is very great.

MR. WHITNEY: You will find that tubercles form more rapidly where the water flows the fastest. You have it in your pipes from the wells for that reason.

PLAN FOR INTERCHANGE BETWEEN LOW AND HIGH SERVICE SYSTEMS.

Henry L. Lyon.

The Water Works in Buffalo were started by a private company, in 1848. In 1868, the city purchased the plant from the private company. At the time of the purchase by the city the machinery consisted of a Double Cornish Bull Engine, with a capacity of 4,000,000 gallons in 24 hours, a Shepard Beam Engine, of 6,000,000 gallons capacity, a Reservoir, holding 11,000,000 gallons of water, and one 24-inch pipe connecting the pumping station with the reservoir. Water was distributed through the city from the reservoir, the daily average consumption being 4,000,000 gallons.

Today, we have a reservoir holding 116,213,827 gallons, which is really a reserve, the pumps pumping into the mains direct, and if more water is pumped than is being used, it flows into the reservoir, if less, is pumped than is being used, it flows back from the reservoir, the daily average consumption being 130,000,000 gallons.

In the pumping station are ten pumps:

No. 1. Worthington Horizontal Compression 430 H. P. 12,000,000 gallons capacity.

No. 2. Worthington Horizontal Comprssion 700 H. P. 20,000,000 gallons capacity.

No. 3. Worthington Horizontal Compression 700 H. P. 20,000,000 gallons capacity.

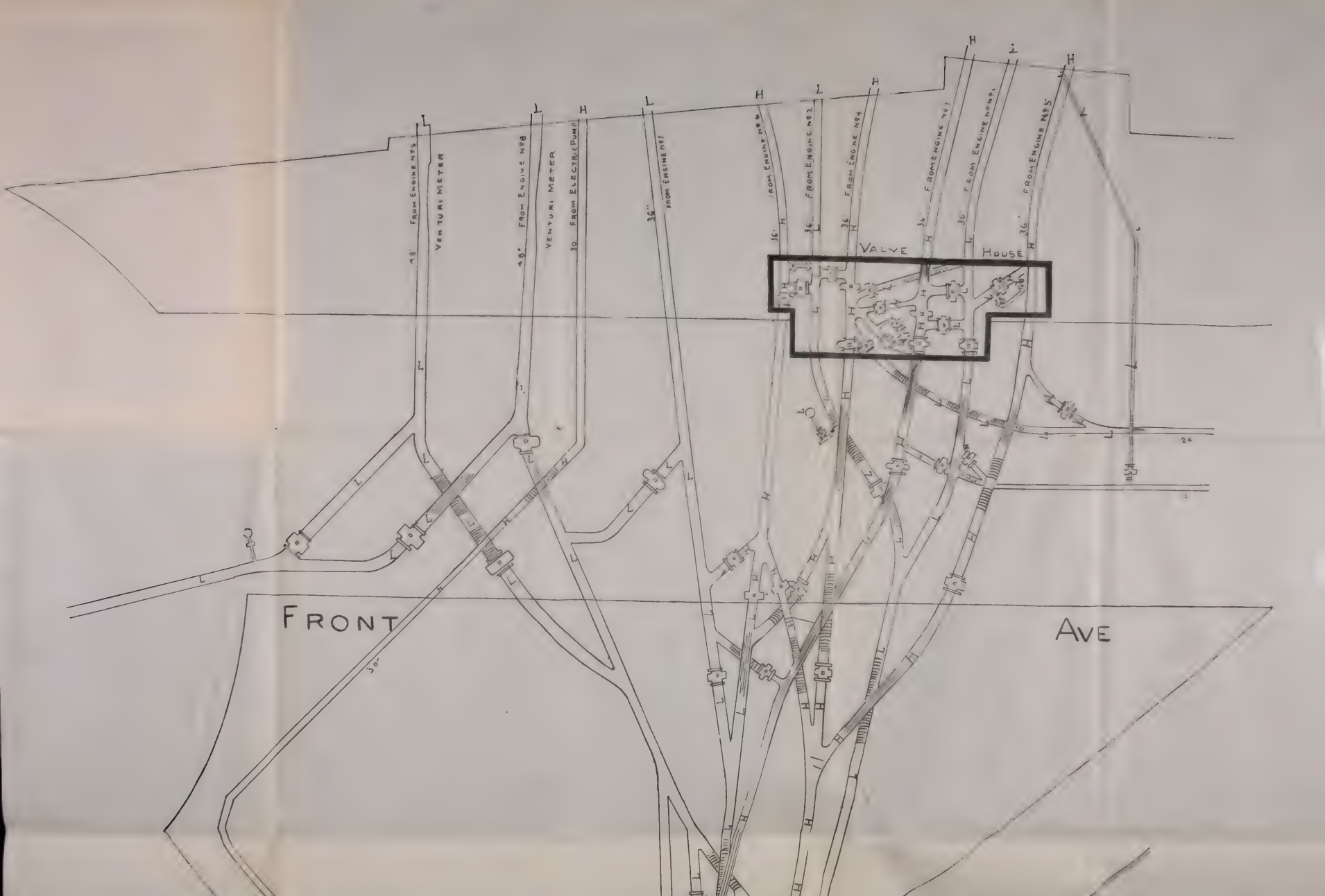
No. 4. Holly Horizontal Compression 550 H. P. 15,000,000 gallons capacity.

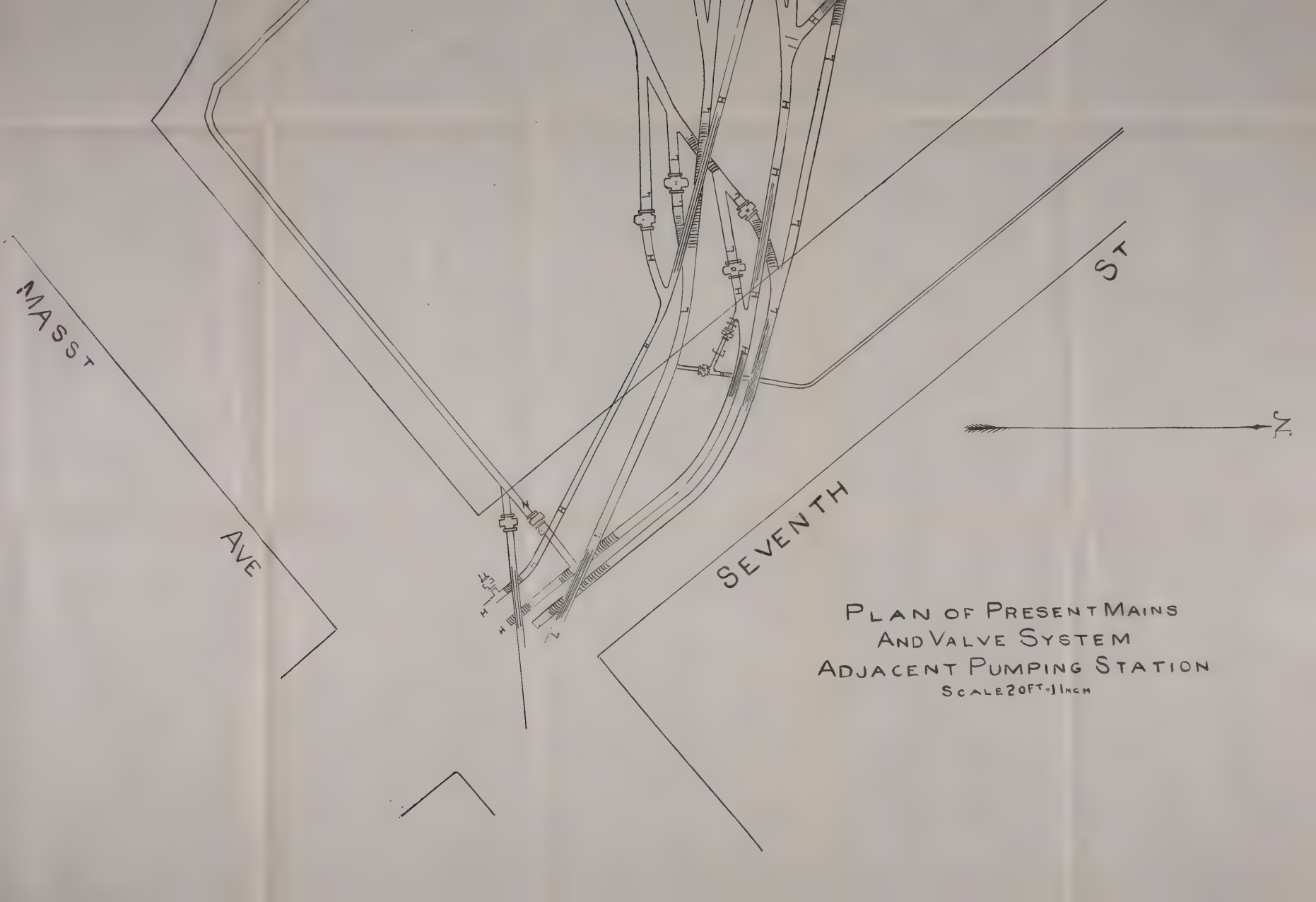
No. 5. Holly Horizontal Compression 700 H. P. 20,000,000 gallons capacity.

No. 6. Holly Horizontal Compression, 700, H. P. 20,000,000 gallons capacity.

No. 7. Holly Horizontal Compression 700 H. P. 20,000,000 gallons capacity.

No. 8. Lake Erie Triple Expansion, 1200 H. P. 30,000,000 gallons capacity.


VALVE HOUSE
FRONT
AVE
VENTURI METER
FROM ENGINE No 1
FROM ENGINE No 2
FROM ENGINE No 3
FROM ENGINE No 4
FROM ENGINE No 5
FROM ELECTRIC PUMP



PLAN OF PRESENT MAINS
AND VALVE SYSTEM
ADJACENT PUMPING STATION
SCALE 20 FT - 1 INCH

No. 9. Lake Erie Triple Expansion, 1200 H. P. 30,000,000 gallons capacity.

No. 10. Snow Electric Centrifugal, 1500 H. P. 25,000,000 gallons capacity.

The Discharge Pipes from engines 1 to 7 are each 36 inches in diameter, from No. 8 and 9 each 48 inches, and from No. 10, 30 inches.

These pumps were installed and the discharge pipes laid at different times during the thirty-nine years the city has operated the plant, and were connected, and cross connected with each other, to meet the situation as it existed at the time.

We have two distribution systems, one 50 lbs., the other 75 lbs. pressure. All pumps being in one station, it is necessary and advisable, at times, to change pumps from one service to the other, and, of course, the distribution pipes in the city must, at all times, be taken care of. It is, therefore, very often a serious problem how to operate the valves to accomplish the result.

One of the annexed plans shows the present complicated situation, better than any description could.

To relieve this situation, I have designed a plan, for a Manifold Valve System, that I believe has never been planned for any water works system, and may be of interest to you. Bids have been received on this plan, and I expect the Common Council will authorize its construction.

The discharge pipes lead from the pumps to a valve house, about 500 feet from the pumping station. The valve house is located here because directly adjoining the pumping station, is the New York Central Railroad, then an abrupt hill, sixty feet in height and then along the top of the hill runs Front Avenue, 99 feet in width, so that this location is the nearest where the ground was practically level.

Nine discharge pipes extend from the pumps to the basement floor of the valve house, each controlled at their entrance into the valve house by a hydraulically operated 48-inch valve; just beyond this valve is a 24-inch T. on each line connected to an air chamber 60 inches by 120 inches, and controlled by a 24-inch hydraulically operated valve.

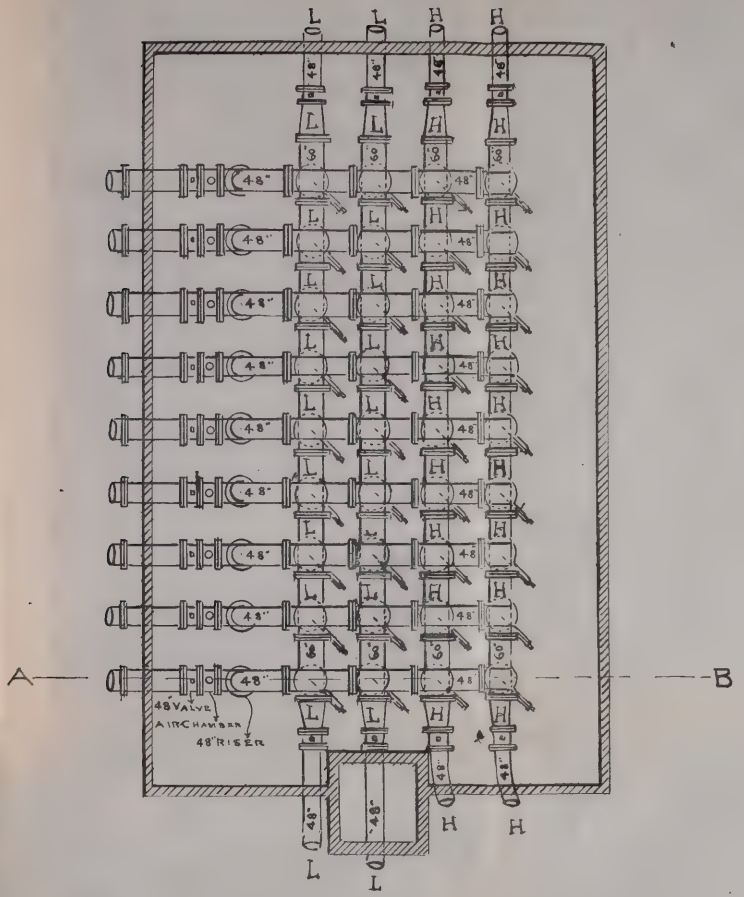
The discharge pipe is then raised by quarter bends, so as to raise the pipes 10 feet above the basement floor of the valve house, and extended horizontally through the valve house, five feet above the pipes for distribution into the city mains.

The pipes for distribution are four in number, two for the high service, and two for the low. They are each 60 inches in diameter, and laid on the basement floor of the valve house, at right angles to the discharge pipes from the pumps.

A 48-inch T. is placed on each of the discharge pipes, over each of the distribution pipes, and a 48-inch T on each of the distribution pipes, under each of the discharge pipes, and between each pair of these T's is a 48-inch hydraulically operated valve lying horizontally. The 60-inch distribution pipes are reduced to 48 inches at each end, and distribute water both ways, being controlled by 48-inch hydraulically operated valves in the valve house.

I annex hereto a plan and elevation.

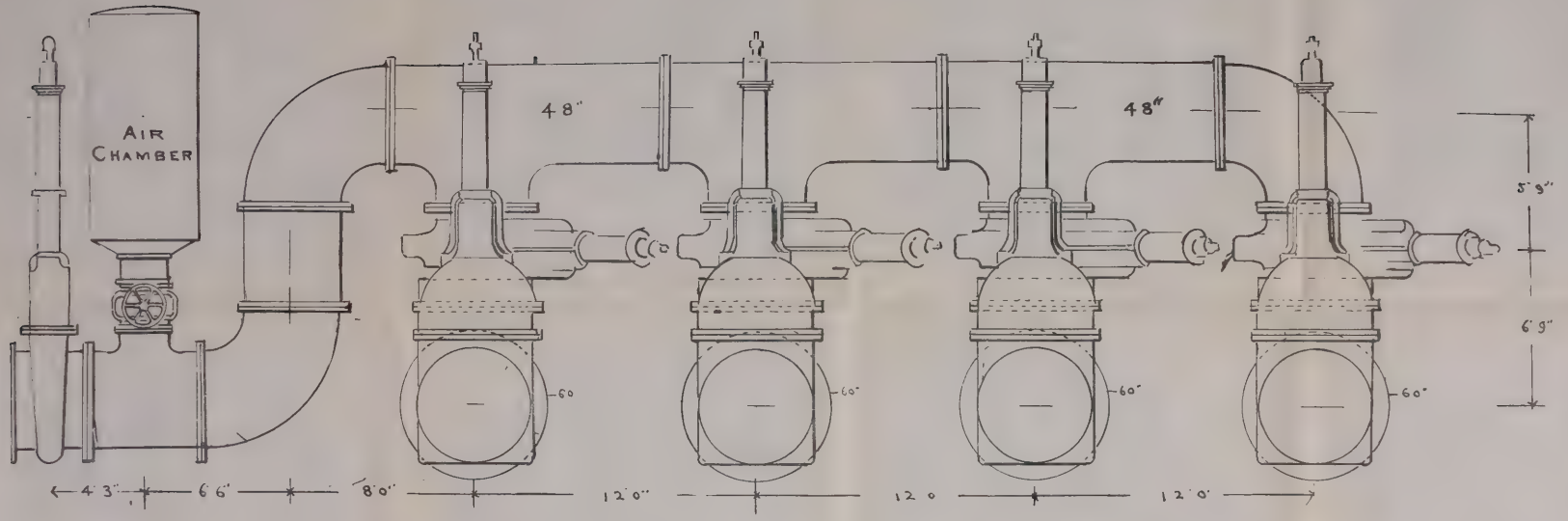
This design will make it a simple matter to turn any pump on to either high or low service, and to change any distribution line from one service to the other. With the hydraulically operated valves two minutes will be suffcient to change from one service to the other, to shut off the pump entirely, or to shut off the distribution pipe entirely. It requires from thirty to fifty minutes now to open or close a 36-inch or 48-inch valve, and to change from one service to the other requires the opening and closing of several valves, and at times a tortuous turning of the water into ways that were never contemplated.



PLAN OF VALVE SYSTEM

L SHOWS LOW PRESSURE MAINS
H " HIGH " "
SCALE 20 FT = 1 INCH

L SHOWS LOW PRESSURE MAINS
H " HIGH " "
SCALE 20 FT = 1 INCH



— SECTION ON LINE A-B —

ALL VALVES TO BE OPERATED WITH HYDRAULIC LIFTS

SCALE 1" INCH = 1 FOOT

SHEET No 1

CITY OF BUFFALO — BUREAU OF WATER
VALVE SYSTEM
HENRY L. LYON ENGINEER
MARCH 1907

see p 212

CUT FOR PLAN OF OLD DISTRIBUTION NOT RECEIVED IN TIME FOR THIS EDITION

DISCUSSION.

MR. FRENCH: I notice that Mr. Lyon's paper reads that the line can be used so that pumps may be run on either high or low service mains. I would like to ask what the difference in pressure is between the high and low?

MR. LYON: One is fifty pounds and the other is seventy-five pounds. The new engines we are putting in will all be constructed heavy enough for either use.

H. F. DUNHAM (By letter): This unique and comprehensive Garden of Gates as it might be respectfully termed, certainly commands attention. It is evidently the result of much study and pretty close adherence to a system.

One passage in the text is not entirely plain. It is to be a simple matter to "turn any distribution line from one service to another". The author's design may enable him to turn a high service into a low service district at will, but if he actually does this he should provide himself with a fast automobile when he visits that part of his distribution system—assuming the conditions to be similar to those in other cities, and that human nature is everywhere nearly the same.

The air chambers with large gates are a trifle mysterious. Is there any reason except weakness of metal for shutting off an air chamber? Were a chamber to burst, the hand operated gate would hardly be accessible. One might inquire why a part of the cost of the gate was not used to make the chamber stronger and the other part for some other purpose.

The efficiency of an air chamber is increased if its major axis lies in the direction of the flow of water instead of at right angles to that direction. Had the air chamber been placed on a nearby 90° bend provided with a flanged connection, it would have offered a better protection from shock and there would have been a saving in specials. But a part of the elevated 48-inch main is an air chamber of good design and capacity even if not supplemented by a small chamber, or a small part of one, at a higher elevation.

Each downward leading connection is provided with a 48-inch gate. Were these dimensions calculated? If it were found that 30 inch gates throughout would not increase the pressure at the pumps under any conditions by more than a fraction of a pound, and under ordinary working conditions by no more than a fraction of a tenth of a pound, there would be some reason for introducing smaller gates. Were the difference in cost between 48-inch and 30-inch gates to be expended in locating, by pitometer or other device, the enormous waste and in preventing said waste, the fraction of a pound and of a tenth of a pound pressure would not have to be reckoned with; nor would several more pounds, against which the pumping machinery is now obliged to labor.

A part cannot be made greater than the whole, but a part may be designed with regard to the value of the works as a whole.

REMODELING OF DISCHARGE PIPES SPRINGFIELD AVE. PUMPING STATION, CHICAGO, ILLINOIS.

W. A. Levering, Superintendent, and H. S. Baker, Engineer Water Pipe Extension.

The City of Chicago in 1905 and 1906 added 178,000,000 gallons to its daily pumping capacity by the installation of pumping engines as follows:

Three Reidler pumps at Chicago Ave. Sta., at 25,000,000 gallons each,	75,000,000
One Worthington pump at Springfield Ave. Station,	40,000,000
One Worthington pump at Central Park Avenue Station,	40,000,000
One Snow pump at Hyde Park Sta.	20,000,000
One Horizontal Compound, Allis-Chalmers, Washington Heights Station,	3,000,000
Total	178,000,000

Prior to these additions the total pumping capacity of the 10 stations was 528,650,000 gallons per day, making the present pumping capacity of the City Water Works 652,000,000 gallons per day, allowing for old engines taken out and scrapped.

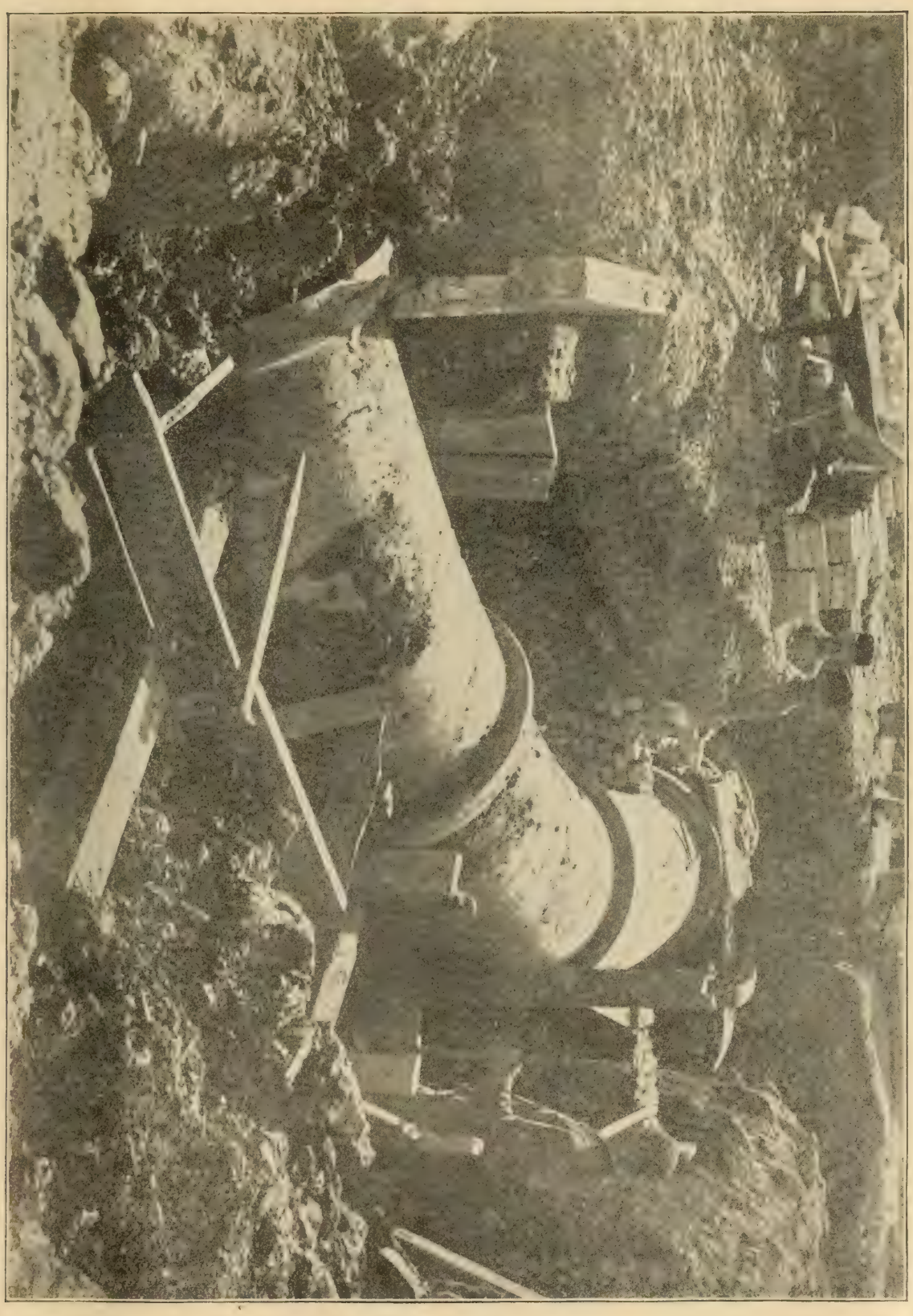
Plate No. 1 shows the general distributing pipes 24" and larger in diameter throughout the City, all of which was interconnected. In this way adjacent stations take up the work when a pump at any station is temporarily shut down.

In connection with the installation of the new

pumps, changes in the discharge systems at all of the above named Stations were made.

At the Springfield Ave. Pumping Station, in order to provide the discharge desired, it was found necessary to entirely remodel the discharge system, at the same time keeping the Station in operation, so as not to draw too heavily from other Stations feeding into the same territory.

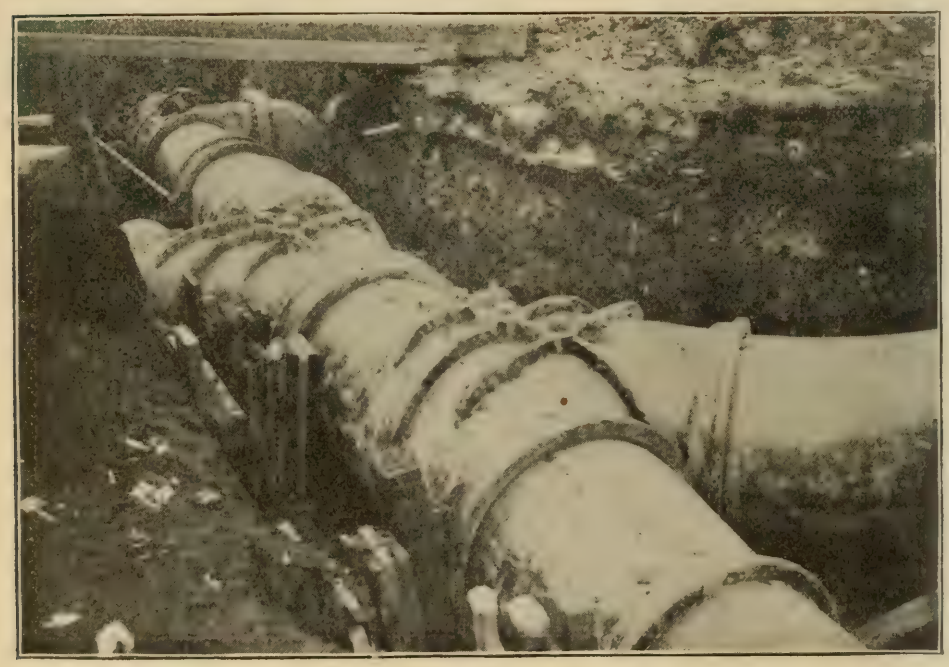
This presented an interesting problem, which was solved by laying the discharge in consecutive steps, so



that at no time were more than two pumps out of service simultaneously.

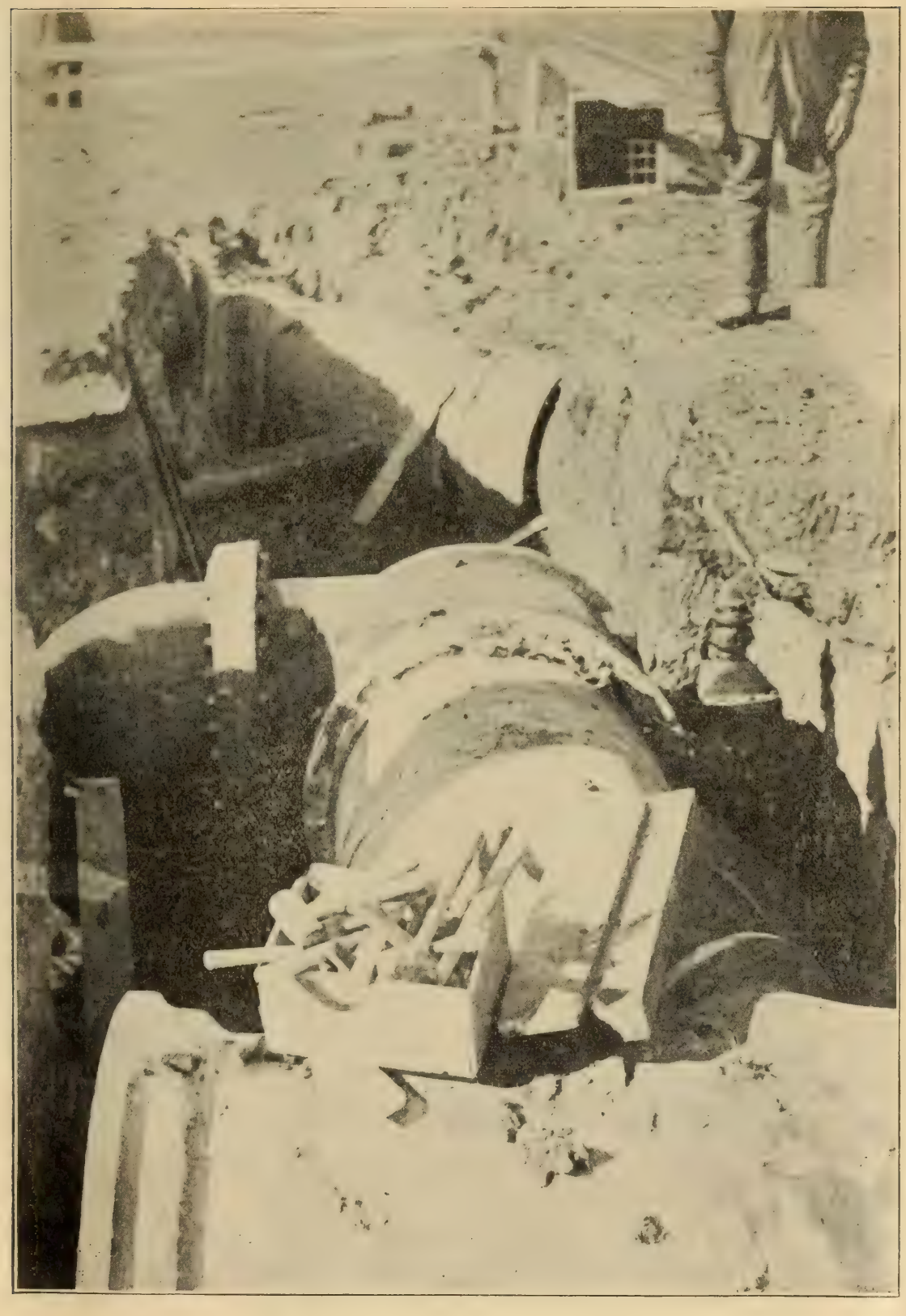
All material was delivered on the ground prior to the starting of the work. The work was done by the Water Pipe Extension Division of the Bureau of Engineering, with a force composed of an Asst. Engineer, one Asst. Foreman and an average of four caulkers and 25 laborers. At several different times the work was stopped between the different steps to avoid stormy winter weather.

The material was handled with a heavy pipe laying



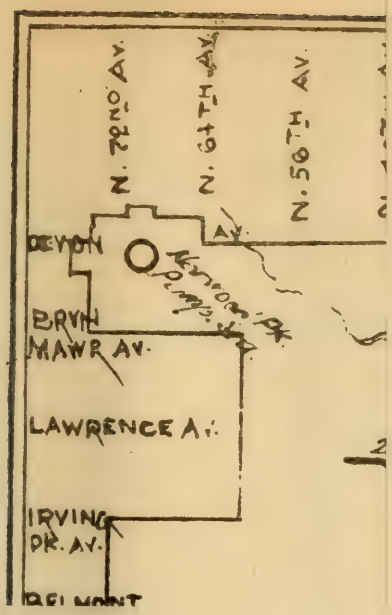
derrick of Standard Chicago design, was started Sept. 7, 1906, and was completed about March 1, 1907. The soil was yellow clay, and the digging very hard on account of frozen condition of the ground, the work being done at this time when the draft on the pumping station was much lighter than during the warmer weather.

In designing this discharge system, especial attention was given to the placing of valves, so that each step in the work could be carried on as planned, and when completed would permit of any pump being shut



down without interfering with the main discharge system.

The various steps in the work was shown in accompanying drawings. In step No. 1 the 36″ valve was strapped to a special iron collar bolted back of the bell


N. 72ND AV.
N. 69TH AV.
N. 56TH AV.
DEVON
AV.
BRYN
MAWR AV.
LAWRENCE AV.
IRVING
DR. AV.

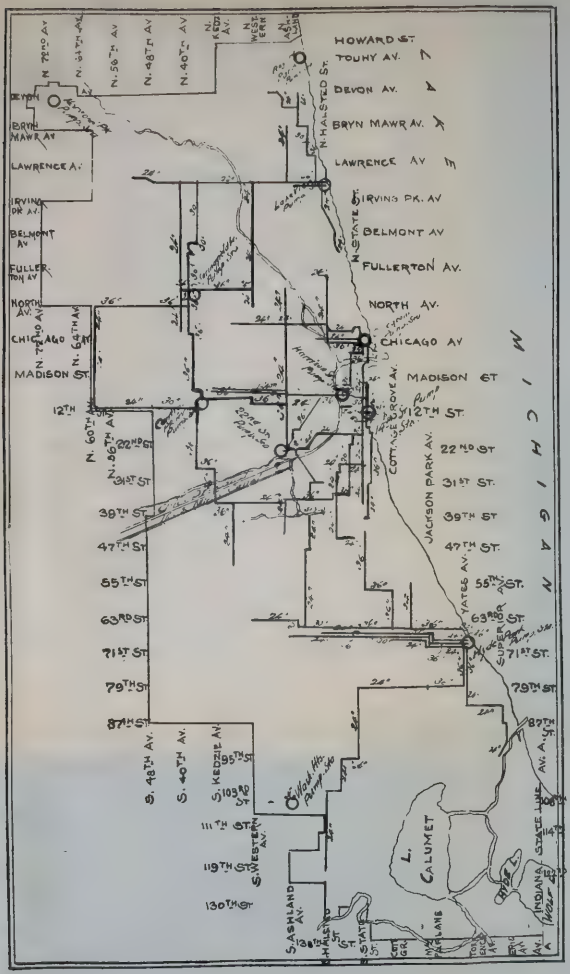


PLATE #1

Showing Pumping Stations and Distributing Mains 24" and larger. City of Chicago.

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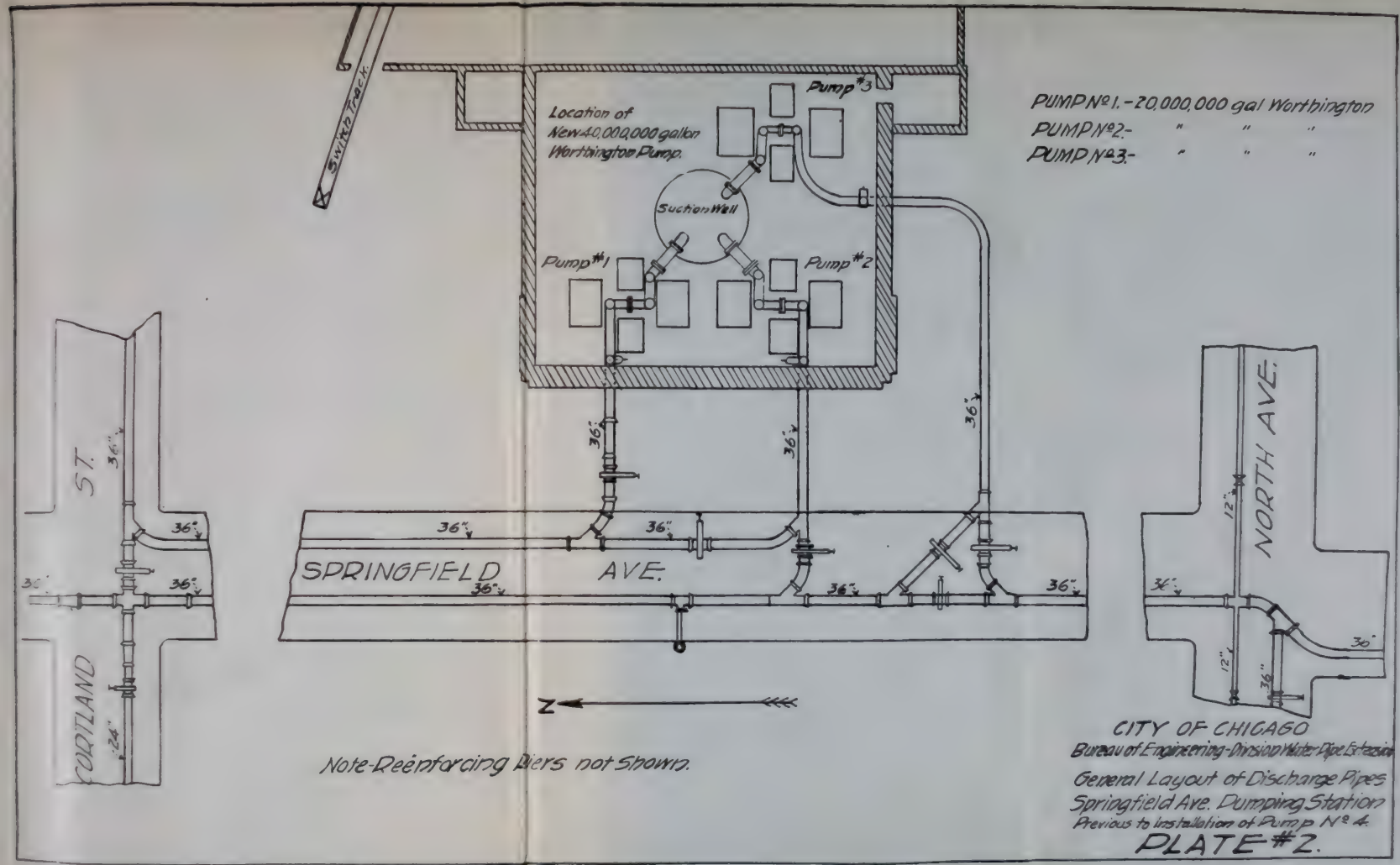
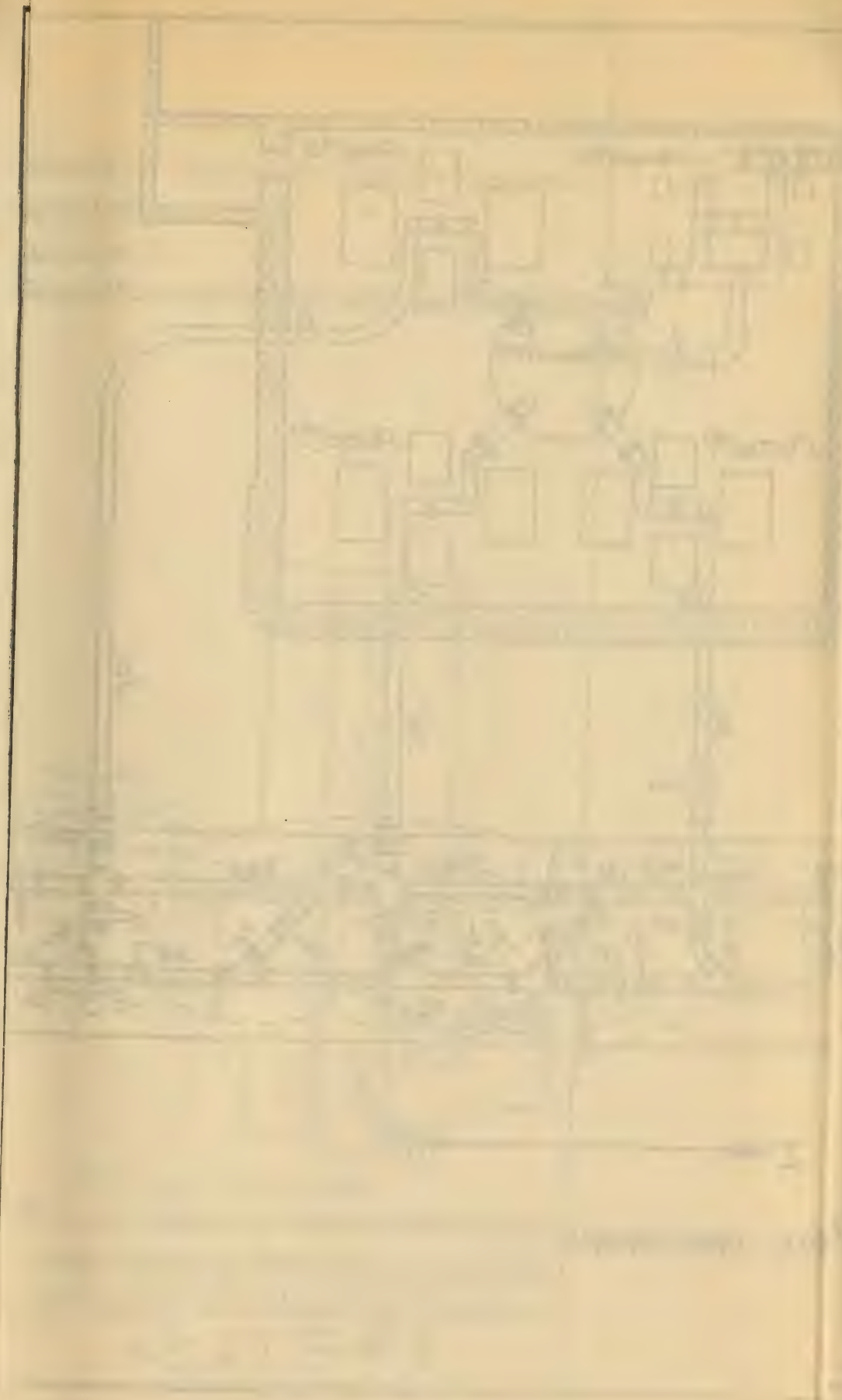
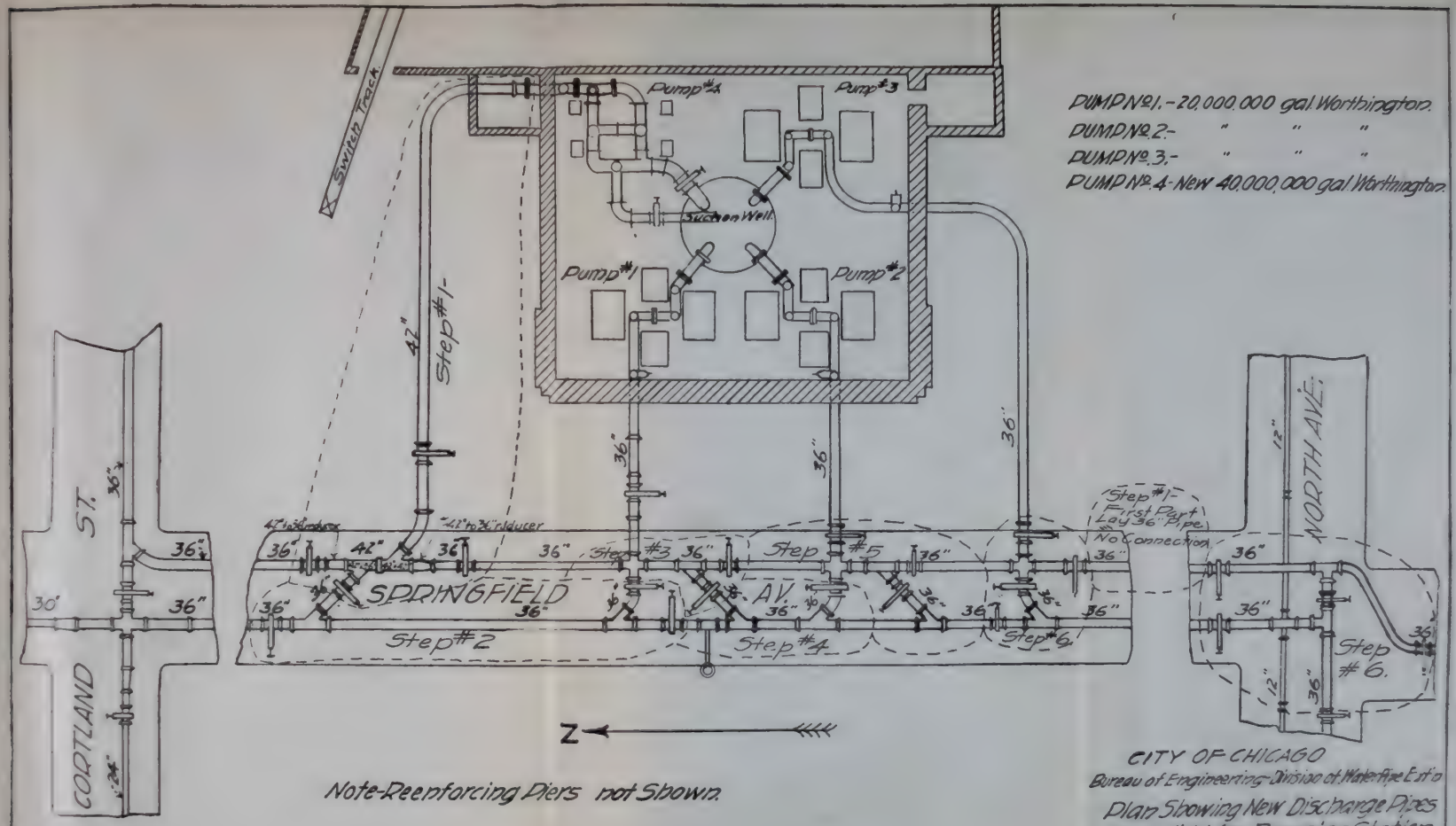
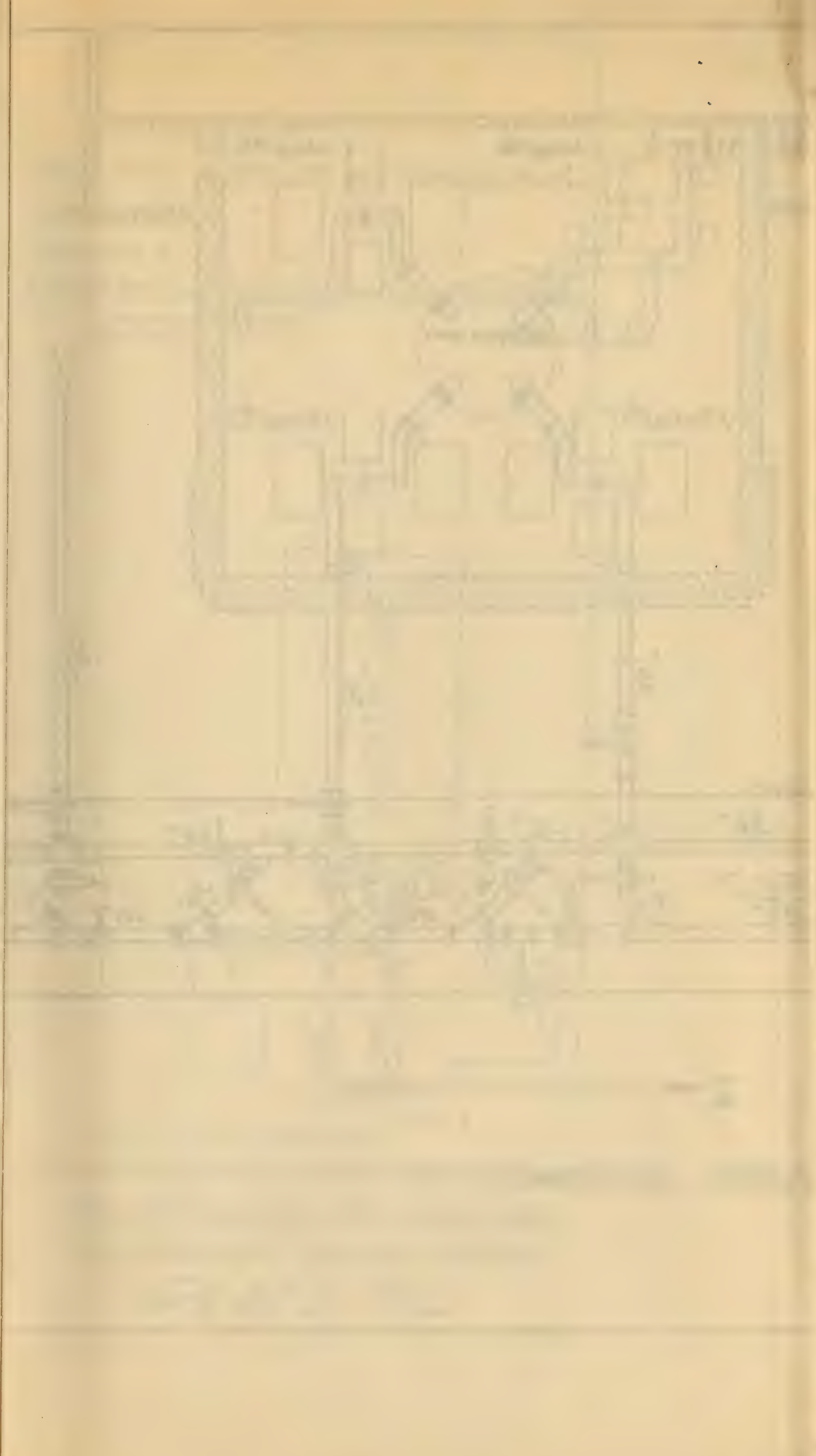
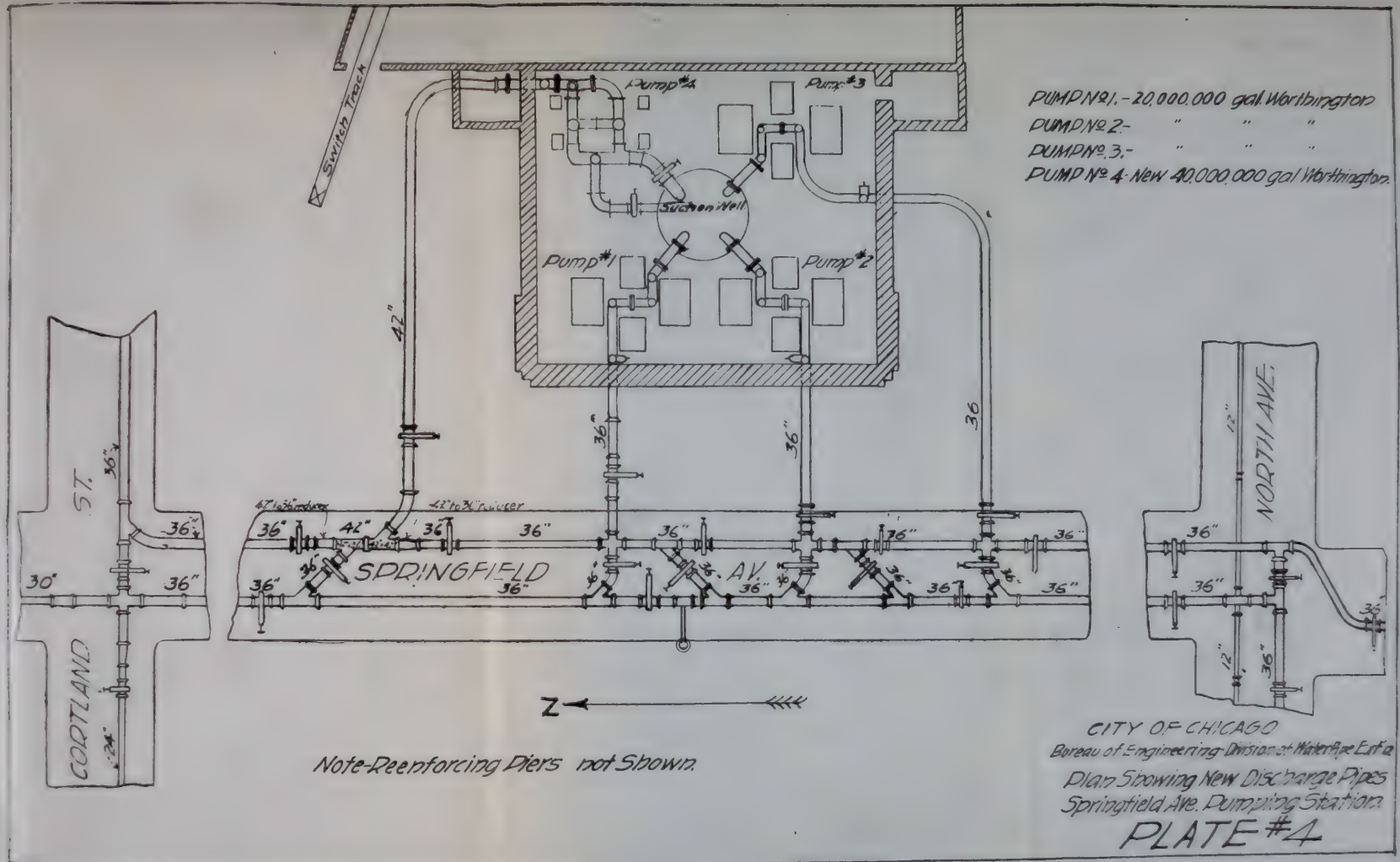

Siding Track.
Location of New 40,000,000 gallon Worthington Pump.
Pump #3
Suction Well
Pump #1
Pump #2
PUMP No 1. - 20,000,000 gal Worthington
PUMP No 2. - " " "
PUMP No 3. - " " "
36"
SPRINGFIELD AVE.
PORTLAND ST.
NORTH AVE.
12"
30"
24"
Z
Note-Reëinforcing Piers not Shown.
CITY OF CHICAGO
Bureau of Engineering-Division Water Pipe Extension
General Layout of Discharge Pipes
Springfield Ave. Pumping Station
Previous to Installation of Pump No 4.
PLATE #2.




Switch Track
Pump #4
Pump #3
Suction Well
Pump #1
Pump #2
PUMP No 1. - 20,000,000 gal. Worthington.
PUMP No. 2. - " " "
PUMP No. 3. - " " "
PUMP No. 4 - New 40,000,000 gal. Worthington.
42"
Step #1
36"
Step #1 - First Part Lay 36" Pipe. No Connection
NORTH AVE.
12"
ST.
CORTLAND
30'
SPRINGFIELD
AV.
Step #2
Step #3
Step #4
Step #5
Step #6
Z
Note-Reenforcing Piers not Shown.
CITY OF CHICAGO
Bureau of Engineering-Division of Water Pipe Extn
Plan Showing New Discharge Pipes
Springfield Ave. Pumping Station.
PLATE #3

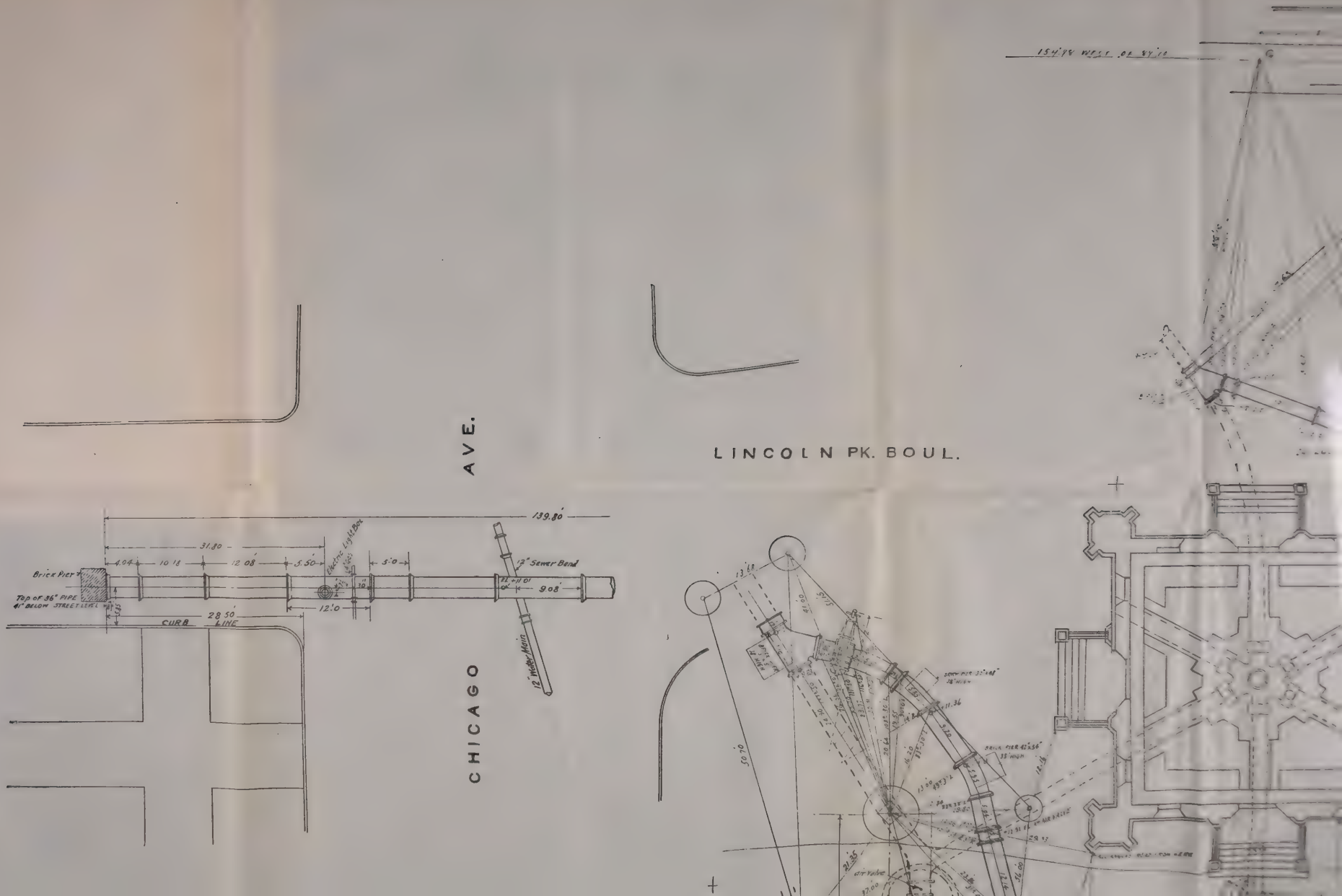




PUMP No 1. - 20,000,000 gal Worthington
PUMP No 2.- " " "
PUMP No. 3.- " " "
PUMP No 4 New 40,000,000 gal Worthington

Note-Reenforcing Piers not Shown

CITY OF CHICAGO
Bureau of Engineering-Division of Waterways Extn
Plan Showing New Discharge Pipes
Springfield Ave. Pumping Station
PLATE #4


CHICAGO AVE.
LINCOLN PK. BOUL.
154'98 WEST OF SW 1/4
139.80
31.80
4.04
10 18
12 08
5.50
5'0
Electric Light Box
12" Sewer Bend
9.08
Brick Pier
Top of 36" PIPE 41" BELOW STREET LEVEL
28.50
CURB LINE
12'0
12" Water Main

PT L" IS ON ℄ ENGINE 231.1 ft WEST OF FACE OF WATER TABLE OF BLDG.

20' 20' 20' 20' 85'8 0

"G" "C" "E" "D" "F" "H"

90°

PT OF 24" FIRE

Y BRANCH BEDDED IN REINFORCED CONCRETE

24" LUDLOW

36" LUDLOW

36" LUDLOW

36" LUDLOW

36"-⅛ BENDS.

CONCRETE PIER

CONCRETE PIER REINFORCED

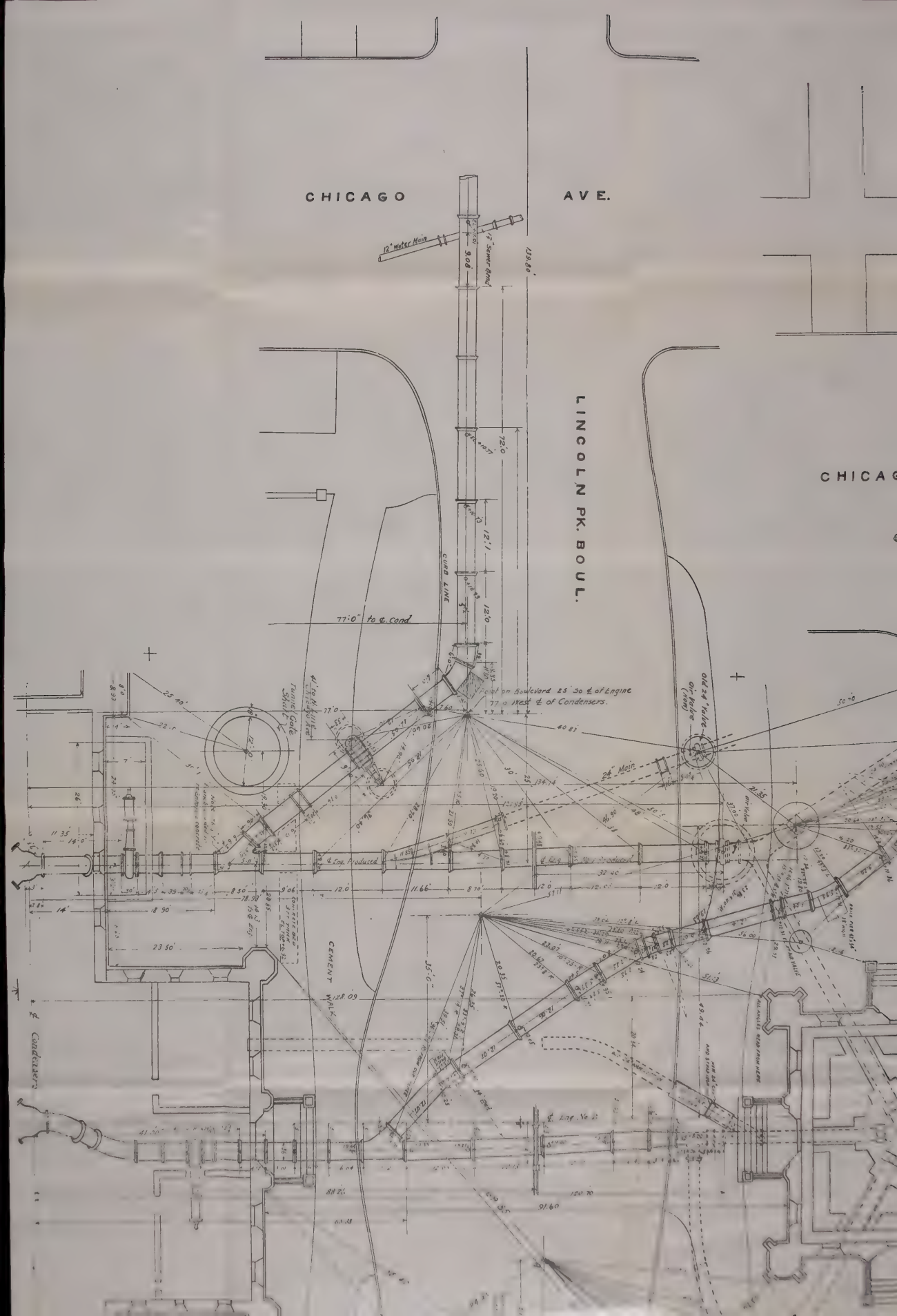
CONCRETE PIER

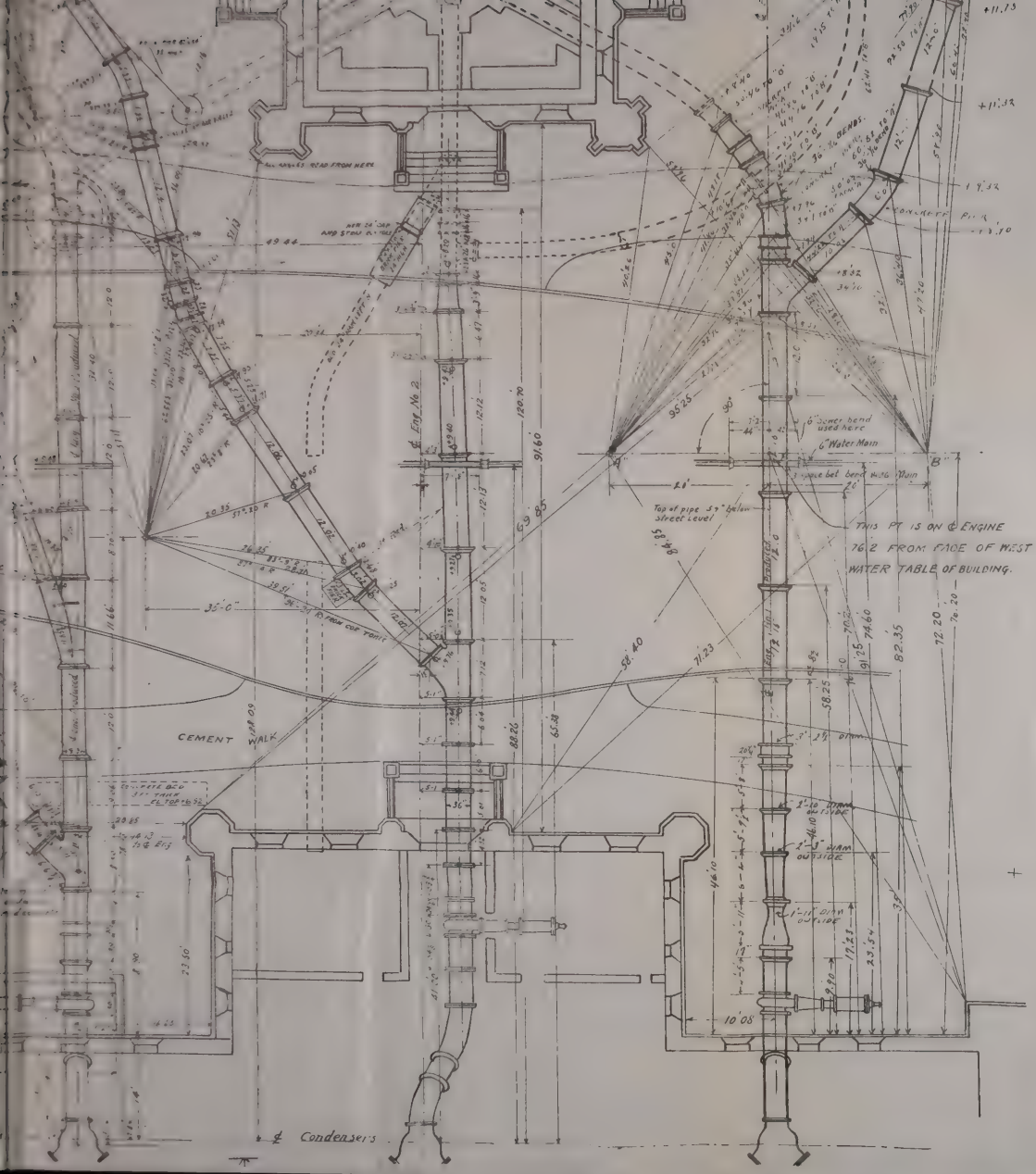
CONCRETE PIER

℄ ENGINE NO. 1. PRODUCED

ALL ANGLES READ FROM HERE

"H" TEST HYD


CHICAGO AVE.
LINCOLN PK. BOUL.
CHICAG
12" Water Main
4" Sewer Bend
139.80'
9.00
12.0
12.1'
12.0
CURB LINE
77:0" to ℄ Cond.
Point on Boulevard 25' 30 ℄ of Engine
77.0 West ℄ of Condensers.
Old 24" Valve
24" Main
℄ Eng. Produced
CEMENT WALK
35'-0"
℄ Condensers
℄ Eng. No 2
BRICK
91.60


CEMENT WALK
6" Water Main
Top of pipe 57" below Street Level
THIS PT IS ON ℄ ENGINE 76'2 FROM FACE OF WEST WATER TABLE OF BUILDING.
℄ Condensers

of "Y" branch, holding valve in place after pump No. 4 was started and until step No. 2 was completed. However, in the other steps it was found to be practicable and much easier to block the valves with timbers, leaving the space open in front of the valves, so that the next steps could be taken without interfering with blocking.

Masonry and concrete piers were placed as rapidly as specials were set and concrete foundations were laid under valves.

The parallel 36″ mains were twenty feet apart, center to center, which brought connections so close together that in steps No. 3 and No. 4, the old 1/16-36″ bends had to be cut back for a distance of about 12 inches. It was found possible to place the valves on these cut ends and make the desired connection parallel to the existing lines rather than radial to the bends.

A torch apparatus for melting joints was used, but was not a success, and all joints were burned out by using wood fire.

This work was designed and executed by the Water Pipe Extension, Bureau of Engineering, which Division has charge of the repairs and renewals of the water distribution system of the City of Chicago.

The accompanying plate No. 2 shows the discharge pipes at the Station previous to commencing work. Plate No. 3 shows progress of work by steps. Plate No. 4 shows completed discharge system. Other illustrations show work in various stages of construction.

The total cost of the work was:

Labor and teams	$11,218.79
Material	16,325.16
Total	$27,543.95

HOW CAN POLITICS BE ELIMINATED FROM MUNICIPAL WATER WORKS.

J. M. Diven.

That politics do, in many cases—probably a large majority of cases—enter into the management of Water-Works owned and operated by cities and towns, will not be denied. And that this is not right, is absolutely a menace to the health and welfare of the citizens in many cases, as well as a great financial loss, will not, I think, be denied. Too much depends upon the proper management of a public water supply to make it safe or right to allow politics to control or affect it.

To be a good Water-Works Superintendent or Manager requires, in addition to ability and adaptability, long study and practice. If these Managers are to be changed every time the City administration changes, it is evident that they can never have the experience that they should have to properly perform their duties. No matter how good men they may be, they will still lack the proper training and experience.

This follows throughout the entire staff, office force, inspector, street foreman, meter readers and repairers, enigneers, firemen, in fact the entire force.

Again, will men who only expect to hold the "job" for two or three years, give it the study and attention that it should have? It is not natural that they should, there is little incentive for them to do so; they know that the next election is likely to go the other way, so that they will have to go at some other work.

Then they have other duties to perform, other masters to serve—the men or party that put them in the position. Party allegiance must be observed, at no matter what cost to the citizens. The men are employed for their politics, not for their worth or fitness for the particular position.

Under these circumstances, are the best men always or even usually chosen?—the men fitted for the work?

The public water supply is a matter too all important to be made subservient to politics, or any consideration except that of the very best possible supply of the purest water obtainable. All must use water, if it is pure and good, the health of the people will be good and the community will be prosperous; because if it is a healthy city with a low typhoid death rate, home seekers will be attracted to it. But without proper supervision and management the purity of the water will, in most cases, always be in danger.

These political changes are often brought to the writer's attention in his capacity as Secretary of this Association; one of his duties being to try and keep track of the water works people of America. How frequently he finds these changes—for purely political reasons—going on. How many changes have to be made in our list of members for this reason. In looking back over the years of his connection with the Association, the number of such changes that come to mind, is almost as long as the present list of members.

A man drops out, is not heard from; one of our Associate Members or representatives calls, and in the course of conversation tells of a visit in "Grafton," asked about Smith the old Superintendent, he says "why hadn't you heard? At the last election there was a complete change in the political complexion of the city, Smith and all the old Commissioners are out, Jones is the Superintendent now." The commission is new, the Superintendent is new, just because there has been a change in the political control. Smith was a good man for the position, had had long experience; thoroughly understood the work in every detail, was familiar with the works, knew all their weak points. In his long years of service he had gathered about him a corps of able and trained assistants. The works were well managed, the quality of the water above suspicion, the quantity ample. The management was economical, waste was kept at the lowest possible point. The plant was in first class condition in every detail.

But Smith didn't belong to the right political party. He was not an active politician, but he hadn't helped the party now "in", had in fact, voted against them—hence he must go. No matter if the quality of the water is not kept up, if the quantity is lacking when a big fire occurs, because waste had not been watched. No matter if typhoid fever breaks out, because the water supply has not been properly guarded, and sickness, suffering and death follow. The active politicians, the men who helped the party, must be rewarded.

Jones is an "active politician," he can, in fact, did carry the 17th ward for the party in power. He is a good man, sober, industrious and intelligent. There is nothing against him, no fault can be found with his appointment, so far as character goes. He was a clock-maker and a good one, but had absolutely no knowledge or experience with water-works management.

Then O'Sullivan had a strong pull in the 7th, and controlled many votes, which he pulled for the dominant party. He had run an engine in Alderman Riley's wood yard—he knew the difference between the throttle and the exhaust; hence he was put in charge of the expensive machinery at the Pumping Station.

Stopplebein was a clerk in Meisner's Drug Store, hence knew all about chemistry, water analysis, etc.; and he controlled a large German vote. He was put in charge of the Filter plant, though he had no experience in managing either filters or men.

So down through the line, the entire force is new and inexperienced; holding the positions because of the political work they had done; not because of their fitness or training.

To start with, everything is in the best of condition in all departments, and things run on smoothly enough for a time. The pumping engines respond to the throttle and the exhause is clear. So they run smooth and pump water with no increased expense, no difference is perceptible. But in time, the boilers through neglect, become badly incrusted, and require more coal to keep

up steam. The packing of the engines becomes worn, the plungers worn, the pump valves broken, there is a loss of steam and vacuum, a big "pump slippage," and more coal is required.

Water is being freely wasted, and more has to be pumped and filtered. The filters are overworked, and with unskilled management, soon fail to properly perform their work. Impure water is delivered to consumers, and a typhoid epidemic breaks out.

Then there is trouble, inquiry and investigation. Maybe the State Board of Health is called in, anyhow the trouble is remedied for the present. But the City and State being controlled by the same party, the matter is smoothed over.

Stopplebein has had a lesson; has had experience, and would probably give efficient management as long as the party "kept in," after which more inexperience would follow.

But how can this be corrected or changed?

A city or town constructing a Water Works system, or purchasing the works of the company that had been supplying them, is entering upon a purely business proposition. It is a joint stock operation, in which the property owners are the stockholders. It is their money that will build or purchase the works, their money that will be sunk if the project is a failure.

Now on being asked to put money into an enterprise, its earning capacity and all good points being elaborately explained, what is the first question you will ask? What seems to you of the most vital importance? Is it not, *who will manage the business.*

Should it not be so with the property owners when a water-works project is up? Should they not be informed as to who is to manage their investment?

The Charter of a Municipal Water plant, giving the authority of the State to build or purchase a works. should state who the first commissioners were to be. Their appointment should be for long terms. If there are to be five, let one man be appointed for ten years,

one for eight years, one for six years, one for four years and one for two years.

Then the "property owner stock holders" would know before they voted for the works, who were to manage them for the first several years, whether it was apt to be good management or poor. And the "Promoters" would be apt to select the men who would mean good management—fearing failure to receive the vote of the property holders unless they did. And none but property holders should have a voice in the matter.

At the end of the first two years, when the first vacancy on the Board occurred, the Charter should provide for the election of a successor, to hold office for ten years. And so on, each succeeding two years. With this method, there would always be some men of long experience on the board.

Might we not well go further in the stock holder method, and let each property holder vote according to the value of the property he owned? Let each property owner have one vote for each one hundred dollars of assessed value of his property. Surely the largest property owner has the most at stake, just as the largest stock holder in a corporation has. Some might object that this would put the management of the water works in the hands of a few, in some cases, even, in the hands of one man. But the one or the few would be the most interested, have the most at stake, and be the most concerned that the property be well managed.

This Water Board or Commission being thus formed, should have *complete and absolute* control of the plant, and not be subject in any way to the political division of the city. They should be vested with power to contract for all construction, to appoint or remove all employees, in fact, to manage the works in every way. They would hold office long enough to gain some experience, and being responsible men, they would properly manage the *business,* manage it for the benefit of the "property-owner-stock-holders," as well as the best interest of the city, as the city's prosperity would be theirs.

They would be apt to carefully select the employees, and to retain them in office as long as they were efficient.

Would not this method be apt to insure efficient management?

Compare it with the other method. The Mayor or man elected by the people, without any regard to his being one of the managers of the City Water Works, to be one commissioner; the other two to be elected by the Council on the Mayor's nomination for short terms, one at least going out of office as the newly elected Mayor comes in, thus giving him the appointment of one commissioner, making with himself, the majority of the board. Is this system not one that might lead up to the conditions described above?

But even the plan proposed does not go far enough to insure the most efficient management and the best water for the people. We need more than this, and should look to the State to provide it.

Water supply and sewerage are closely bound together, and should always be considered together. They could properly be placed under the same management; about the same problems are met in each, and the same qualifications and ability required to meet them. Not only because the disposal of sewerage affects the purity of the water supplies of the nation, but also because of their intimate relation to each other.

The conservation by the State of its water resources, should be under the same control as the disposal of the sewage, in order that there may be perfect harmony between the two, that they may be cared for so that the one will assist the other. A result almost impossible under separate management or control.

Every State should have a "Water and Sewage Commission," charged with the supervision of all plans for public water supplies and sewer systems.

Such commission should be non-political or partisan, and be composed of men of undoubted ability, of experience in water supply and sewage construction

and operation—the highest authorities on these subjects—as well as men of integrity.

Their power should be absolute in the control of water supplies and sewage disposal. They should have power to compel changes in the source of water supplies, or the filtration of the present supply, where it was found necessary to insure the health of the community supplied.

Also to enforce the proper treatment of the sewage of a town when it was found that its discharge, in a raw state, into a river, lake or other source of water supply, was endangering the water supply of some other community and the health of its people.

All designs for new water supplies or material extensions of existing ones—involving new or additional sources of supply, or the filtration of existing supplies—all plans for sewerage of towns or for sewage disposal plants, should be subject to the approval of this Commission.

The men who are to have charge of water filtration or sewage disposal plants, should be subject to examination by the Commission, and only appointed on their approval. The examinations for these positions, should be rigid, so that only capable men would have charge of these important works.

But the most difficult question is, how could such commissioners be made absolutely non-partisan, non-political. This is indeed a serious question and one hard to solve.

That there are plenty of men, and women too—eminently fitted for this work, is beyond doubt. Moreover, sanitary science, in its most advanced form, is being taught in the Universities, colleges and technical schools and many young men and women are taking up the study, intending to make this their life-work; so there will be a sure supply of experts fully equal to the demand. Indeed, in a few years, the competition will be so sharp, that it will be the old proposition of the survival of the fittest:—that is, the best qualified will

secure the positions at the top, leaving many less able ones available for the minor positions.

But how to insure that the right ones will always be selected. The ones who have been educated to and for this work, instead of the ones to be "taken care of" for purely political reasons? This is indeed a difficult problem.

It would seem that in matters involving the health —if not the lives—of the citizens, politics, and even commercialism, would be lost sight of. But such surely is not the case; nor will it be until after a long campaign of education or even compulsion. The masses are strangely indifferent to these matters. They calmly permit the dumping of filth into the sources of their water supply, and the pumping of diluted sewage into their homes, until awakened by some terrible epidemic. Then there is a rude awakening, a fuss, investigation, changes in management, etc., then all is forgotten, the epidemic is over and the old indifference returned to.

A POSSIBLE REMEDY.

As a possible remedy, the writer suggests the following, as a step towards the solution of the problem.

FIRST—Let each city or town elect by the vote of its taxpayers a city or town Water and Sewage Commission;

SECOND—Let such city and town commissioners, in convention assembled, select by vote a State Water and Sewage Commission or Board; under constitutional provisions, that one member shall be a well recognized Analyst and expert hydraulic engineer, one a civil and sanitary engineer, with experience and reputation in the designing of sewer systems and disposal plants.

The Commissions or Boards should be as large as the circumstances permit, in order to secure the greatest possible amount of expert supervision. And adequate salaries should be provided for, so as to make the positions attractive to the men of greatest ability in the several lines. The larger and richer States should pro-

vide for Commissioners that would bring to it the best civil, mechanical, hydraulic and sanitary engineers as well as expert chemists. The work of the commissioners would include all of these branches of engineering and science, and it would be well that each be separately represented.

There should also be on the commission, the sound business man, and the lawyer, as questions of finance and legality will come up.

The vote of the taxpayers only, who may be considered as forming the more intelligent portion of the communities—and surely the most interested portion—should insure the formation of proper conventions to select the State Commissioners. For like the municipal purchase or construction of water works, it is a purely business proposition—and the financial consideration still has more weight than the ethical.

Both the local and State Boards or Commissions should be elected for long terms, and all should not be changed at one time, there should always be hold overs —men of practice and experience in some branch of the work.

NATIONAL SUPERVISION

In a country constituted like the United States—and probably the same would be true of the Dominion of Canada—which too is composed of separate states, we need something more.

We want protection of interstate streams or other sources of water supply; this must be the work of the National Government.

So let us take another step, and have conventions of the State Water Commissions to elect a National Water and Sewage Commission, to co-operate with the State Commissions, and have a general supervision of all sewage disposal that might affect inter-state water supplies. And of all large streams flowing through or along two or more States, as well as of other bodies of water bordering on or lying partly within more than one State.

It should be their duty to investigate and conserve the water resources of the country, and prevent all unnecessary pollution of the same. Also to have some general control or influence over the various State Boards, so that the rules, regulations and methods of all should be, in a measure, uniform.

Let us stop and consider what such a National Commission would be like. The cities and towns of each State would vie with each other to send to the State Convention, their best men, as they would, for self interest, if nothing else, want to be well represented. Then the State Commission would send its best men to represent it at the National Convention. And a convention of such carefully selected and well trained experts, could surely be relied on to choose a National Commission that would be worthy of a great Nation; that would be composed of the best men in each line of work. It would indeed, be a grand body of men—or maybe there would be some women—capable of dealing successfully with the most intricate questions of Water supply and sewage disposal.

With these conditions fully carried out by every city, town, State and the Nation, sanitary living, could, in a measure, be enforced, and the people would, in time become educated to the advantagees and necessity of such living.

Sanitation must be compulsory, the time has not yet arrived when the individuals of the masses, or when even communities will adopt the advanced sanitary ideas for purely ethical reasons. The commercial side may appeal to municipalities, but in the writer's opinion, this will only be after some example, worked out under compulsion, has practically demonstrated the money value of the system.

Some will ask, "what is the money value of sanitary living?" The answer is easy. The death rate is lower, and there is less enforced idleness on account of sickness—less loss of labor. Does not this mean money?

The indifference with which cities pour their untreated sewage into streams and lakes, known to be the water supply of other cities, is almost incredible. But it is exceeded by the recklessness with which they continue to take their own domestic water supply from sources into which they know raw sewage is being emptied.

Not many years ago this was the rule—now, fortunately there is a change taking place and considerable attention is being paid to the purity or purification of the water supplies of cities; and some even to the proper disposal of sewage. But it has taken such typhoid epidemics as Butler and Plymouth, Pa., Ithaca and Watertown, N. Y., with their appalling and needless sacrifice of life, to bring this about. Philadelphia and Pittsburg both suffered long and patiently from high typhoid death rates before filtration was undertaken. The intake cribs of Chicago and Cleveland were pushed out into the lake, further and further, at enormous expense, by high typhoid rates.

DISCUSSION.

MR. LEOPOLD: Mr. Diven's paper is, it seems to me, in line with just exactly what ought to come before this Association, which is a national gathering from all parts of the country and is capable of doing as much good as all the local states or municipal associations combined can possibly do in getting public interest aroused in the proper purification of water for municipal supplies. It seems to me that one thing that has been neglected is the character of water that is being supplied to municipalities. A great many of the States of the Union have laws which provide penalties for the contamination of rivers and lakes and other sources of supply, and the State governments of some of the States have departments which are investigating the character of their supplies for potable uses. The United States Government is doing some work along that line in the Agricultural Department and also in the Geological Survey. Some time ago I entered into correspondence with a number of the Boards of Health of the different States, to find out if possible what legislation had been enacted or was in contemplation relative to the protection of the water delivered to consumers. In the course of that investigation I found that there had been a paper issued by the Geological Survey, written by Mr. Goodell, giving a review of the laws preventing the pollution of interior streams of the different States. The States are classified into three divisions; first, those which provide severe penalties for pollution of streams, comprising about eight States; secondly those providing partial protection, comprising about seventeen States; and lastly, those having absolutely no laws of any kind looking toward the protection of the water supply. Practically all of those States, however, have laws which protect the user as to articles of food and drink; but those laws do not specify how the food and drink shall be prepared for public consumption. They do, however, prescribe the character of the food when it goes to the public and is offered for sale. That, it seems to me, is an important point as to all articles for consumption, whether food or water, and water more than even articles of food. We know that great epidemics are caused by the use of impure water. According to the statistics in

the U. S. Census Report, there are something over 35,000 deaths annually from typhoid fever; and that, of course, is but a portion of the cases that have occurred during the same period of time. I doubt very much whether adulterated foods are responsible for more than a very small fraction of the deaths, and yet we find that the laws of all the States very carefully specify the character of the food which must be offered for sale. We have also lately seen the National Government passing laws to protect the people against adulteration of food. All the evidence tends to show that the protection of water is very much more essential than that of food. I believe we have advanced far enough in our knowledge of water and its proper purification to be able to establish a standard of purity which all municipalities and water companies who deliver to consumers should respect, and if they fail to maintain this standard a penalty should be imposed sufficiently heavy to compel them to do so.

Some of the State laws, one State in particular, that I investigated, provide a penalty against a private water company delivering water which has been contaminated, but excepts municipalities from the operation of said law; in other words, it permits the municipality to furnish water of a character that it prohibits a private company from furnishing. That, of course, is absolutely unjust.

The laws of the different States covering pollution of streams vary greatly. Last winter, Dr. Barchfield, Congressman from Pittsburg, introduced a bill in Congress for the establishment of the National Board of Health. It seems to me that that is a move in the right direction; but the Boards of Health of the different States, even if proper legislation were enacted, establishing a standard of purity of water supplies to be furnished to consumers, it seems to me are not composed as they should be to properly handle the water question, with the exception of two or three States which have established adjuncts to their State Boards of Health in the way of water commissions or engineering departments. Physicians may be able to pass on the quality of water when they know what it is; but their education is not such as to enable them to judge of the best method

or means of securing the desired character of water. That is almost purely an engineering problem, and a Board of Health that is given the control of the water supply should be composed of a certain percentage of men having engineering skill and knowledge under whose department the water supplies should come. The only way, it appears to me, that we can get uniformity in such things is by cooperation of the various interests that are now looking toward a general improvement of the water supply. The subject has taken up a great deal of time of this Convention for several years, and the American Public Health Association has spent considerable time on it. The two departments of the government I mentioned, and the Boards of Health of the different States at their Conventions, have considered this subject. I think that now is a good time for this Convention to appoint a permanent Committee to meet with the committees of the other associations with a view of merging the united influence of the various associations in an effort to secure uniformity of the laws governing the water supplies of the different States, and also to use that influence toward the establishment of a National Board of Health which would have a department of water supply, under competent engineering authority, and which would establish experimental stations where exhaustive experiments could be made as to the best means of handling the waters of the different sections of the country to secure the best grade or highest degree of purification. I do not believe that we could establish a committee that would put in their time to better advantage or more greatly benefit the people of the country than a committee with that object in view.

SECY. DIVEN: It does not seem to me that the Board of Health is the proper body to take up this matter. These questions of water supply and sewage are engineering problems pure and simple. I think what we want is a Board composed of engineers, men who have had experience in the construction of water works and sewerage systems, and sewage disposal plants.

MR. LEOPOLD: I agree with that entirely. I think that this Association, as it is national in character and com-

posed of a large number of the States of the Union, can bring influence enough to bear in the various communities to carry the plan along to a conclusion. It is not a matter of one year or of two years even, but the influence should be carried along to an ultimate conclusion, and it cannot help but result in great good in improving the character of the water supplied to every municipality. As an example of State Boards of Health—I will not mention names—but a filter plant was completed not long ago a report on which I received a few days since from a health officer as to bacterial results. The raw water was low in bacteria, containing about 330 per c c.; and on 100 c c. it was positive in coli results. The filtrate showed 16 bacteria per c c., and a negative coli result on 100 c c. of water. The letter that I got stated "that the water showed some evidence of purification, but I can readily see that it was not yet up to standard." I do not know what he wanted as to standard, but that I think is a little bit more than the majority of the communities would ask. It simply requires a degree of knowledge that an officer in that position lacks.

MR. BARTOW: I have noted what Secretary Diven and Mr. Leopold have said on this subject, and would like to call attention to the action of the American Public Health Association in forming a committee to advocate the formation of a National Board of Health.

The American Public Health Association is made up, for the most part, of physicians, but has a number of members, who are chemists, bacteriologists or hygienists. It seems to me appropriate that this body of engineers and waterworks men, who are vitally interested in pure water, should co-operate with the committee of that organization in advocating the formation of a National Board of Health.

MR. LEOPOLD: I would like to state further that I am in correspondence with Dr. Barchfield, who introduced the bill in Congress last winter for the formation of a National Board of Health, and that he states that he would welcome any assistance or suggestions in regard to its scope and character.

MR. DIVEN: While I heartily agree with Professor Bartow, that this association should, through its Committee

on Water Supply Investigation—or otherwise, do all in its power to further the appointment of a National Board of Health; yet I still contend that Boards of Health, either Local or National, are not the proper bodies to handle the matter of water supply and sewage. I firmly believe that we need Boards, local and national, to handle these two questions alone. Boards composed largely of engineers, for the problems to be solved are almost entirely in the engineering field. We have had Boards of Health for many years, and little has been done by them to improve water supply and sewage conditions. I believe that there is work enough for the Health Boards, even when a national board is established, in other fields. I, also, believe that there is work enough for a National and State Boards in the control and regulation of Sewers and Water Supplies.

I think we need the National Board of Health, as suggested by Professor Bartow, and am ready and willing to do all that I can to assist in the creation of such a board, and to cooperate with it when established. At the same time I think we need the Water and Sewer Board just as much.

DOWSING.

Chas. Anthony, Jr.

Though the writer has no personal experience of the Rhabdomancist's art, he has, as the result of a study of the vast mass of evidence accumulated, long had an open mind on the subject.

Indeed, were it not for the fact that no plausible theory has yet been advanced of the cause of the alleged re-action, he is of opinion, that an impartial sifting of existing evidence, could have no other issue, than an acceptance of the Rhabdomancist's claims. This desire to find an explanation, however improbable, is strongly exemplified in Sir William Preece's suggestion, that the Rhabdomancist detects the presence of water, through the faint earth tremors set up by its underground flow.

Nothing short of an overpowering conviction, that a judicial study of the evidence, left no loop hole, but the acceptance of the Rhabdomancist's power, could in the writer's opinion have led to the enunciation of so improbable, not to say impossible, a theory.

The movements of underground water, which there is strong, if not indeed overwhelming evidence to prove, have been detected by Rhabdomanicists, having been in many cases so slow, as to be unable to generate earth tremors detectable by even the most inconceivably sensitive organism.

Though this explanation cannot therefore be accepted, and despite Sir William Preece's dictum, that the Rhabdomanal power cannot have an electric origin, the advance which has recently been made in the study of radio active phenomena, suggests a possible, though the writer will not go so far as to say, a probable, explanation of the modus operandi.

As is now known, all matter possesses more or less radio-activity, whether inherently or on account of the presence of faint traces of the known radio active elements, does not affect the present argument. Radio

activity can be more easily detected by the ionization, and consequent electro discharging phenomena, than by any other means. Certain substances, such as metals, water, etc., cut off, more or less completely, emanations which give rise to the measureable electric effects. If the Rhabdomancist is gifted with an electro-metric faculty and Kerby and Spence state that insects are much excited by electric states of the atmosphere, which as suggested by Lehmann, they possibly detect through their antennae, the equivalent of the Rhabdomancist's *virgula divinatoria,* whilst the effect of thundery weather on many human beings is notorious, then a possible explanation of the Rhabdomancist's art is within measurable distance. For, if we assume that the earth's substance is on the average endowed with a certain degree of radio-activity per unit of volume, and that the plane of saturation of underground water prevents the emanations from the lower ground reaching the surface, it is clear, that the ionization, and consequent discharging effect, will vary with the depth of the subsoil water.

We have here at all events a possible explanation, sufficient in the light of the vast amount of favorable evidence accumulated to incline the writer to give credence to the Rhabdomanal faculty.

Incidentally this theory opens up the possibility of Dowsing scientifically by instrumental means, with the advantage, of both eliminating the charlatinism which has hitherto unfortunately been only too often prevalent, and of permitting of a more accurate diagnosis.

REPAIRING A BROKEN FORCE MAIN

C. W. Wiles, Delaware, Ohio.

The sixteen inch force main supplying the City of Delaware, Ohio, with water from the pumping station three miles north of the city, runs parallel with the highway.

About two and one half miles north of the city it passes over an arched stone bridge which crosses a small stream, which, after heavy rains often became a small torrent. The pipe line crosses the stream below the bridge and was not fully covered with earth, the top of the pipe could be seen through the water.

This stone culvert had heavy side walls covered with large slabs of cut stone. In March, 1898 occurred a very heavy rain fall, in fact a cloud burst, filling the valley above the bridge with a lake of water; the opening in the stone culvert was about eight feet high by nine wide, and was completely filled with water, the heavy rush of water undermined the foundations and the bridge fell.

It is supposed that one of the heavy cap stones of the bridge on the down stream side fell and squarely striking the water main, which at this time was under a pressure of about 50 lbs. broke out a piece about five feet long.

This occurred at about eight o'clock in the evening, and the supply to the city was at once cut off, it was some hours before the location of the break was learned, and on account of the high water nothing could be done that night.

The next morning it was found that about three feet of water was flowing over the broken main, and as it would take too much time to attempt to pump the water around the break, the writer at once set a gang of men at work uncovering the pipe for some forty feet each side of the break, with a view of raising the broken ends at the stream and putting in a temporary line.

A large derrick was brought and erected over the pipe on one side of the break; after three joints of pipe had been uncovered and the partially broken length in the water had been entirely cut by charges of dynamite, an attempt was made to raise the end of the broken main on the south side of the stream, but failed, then four iron jacks were placed by

the side of the pipes, and with their assistance the broken end was raised in about thirty minutes, over three feet, clearing the stream of water.

By the same operation, the main on the north side of the stream was raised, the lead joints giving sufficient so that no damage was done to the main.

While the broken pipe was being taken from the joints a bridge was thrown across the stream.

We now had the two ends of the pipe above the water, with one twelve foot length broken entirely out.

The writer hoped to insert a twelve foot length without cutting, and the use of a sleeve, as is usual, and to connect up the line with a solid length of pipe.

We then jacked the north end of the broken line up several inches more and moved it to the east about a foot. The south end was carried about a foot in the opposite direction, and an attempt made to roll in the twelve foot length. The bell end of the new pipe was carried over the spigot end of the old main, and the spigot end of the new pipe to the bell end of the old main, then the two ends of the old pipe were brought back into line again, and we had a solid twelve foot length in place of the broken one.

Lead joints were run and calked and the pressure turned on, and with some slight calking of the other joints all were found as good as before the break.

This entire job, including transportation of men and material 2 1-2 miles, was completed in less than twenty-four hours, with the use of one twelve-foot length of sixteen-inch pipe.

This repair left the pipe line some three feet higher than was desirable, so the trench was left open and after a few weeks, when the water in the stream was low, the entire line was let down to its bed, by undermining the pipe, and since that time there has been no trouble.

To have attempted to coffer dam the break and carry the water around, or pump it over the line, would have required several days' work, and the insertion of a solid twelve foot length, in place of two pieces and a sleeve, saved at least twelve hours work.

The fact that the city was without water or fire protection made every hour saved, of great importance.

REPAIRING BROKEN SUBMERGED PIPE LINE.

By Harry A. Lord, Superintendent of Water Works.

Ogdensburg, N. Y.

When the energetic Secretary of this Association wrote me early this spring, suggesting that I prepare a short experience paper to be read at the Toronto Convention, I forthwith consigned his invitation to the waste basket, and mentally thanked him for the compliment; but when several weeks later he followed it with another letter in which he said "I mean you" . . . "You, do you understand!" I readily assented, believing it to be my duty to render what assistance I could, and never doubting but that a Water Works Superintendent who claims to have been longer in the Water Works business in proportion to his years, than any other member of this, or any other Water Works Association, must of necessity have had many experiences well worth relating; but a mental review of the years that have gone with their happenings, forces me to acknowledge that none of my experiences have been particularly interesting or novel; and while at the time I was undergoing them, they perhaps seemed to me to be the most important problems in the wide world, yet in no particular instance was there a large amount of grey matter expended in their solution.

However, I will relate one which mayhap by suggestion will help some other fellow out of a similar difficulty.

The City of Odgensburg, N. Y. is divided into two sections, known as the "East and West Sides", by the Oswegatchie River, which is the third largest river in the state.

The water works, which is owned by the Municipality, is a system of direct pumpage into the mains. The Pumping Station is situated at the easterly end of a dam which crosses the river in the central part of the City, furnishing power for the pumping station and a large number of mills and manufacturies.

The system of distribution of the East and West sides are connected by two submerged water mains.

One, which crosses the river above the dam is of eight inch wrought iron, galvanized pipe, while the other crossing in the swift water below the dam, up stream from a heavy plate and girder bridge is a twelve inch cast iron main, 350 feet long, put together with Ward Flexible Joints. This pipe line which was laid on the natural bed of the river without trenching, in an average depth of eight feet of water was put down in August, 1898 and had therefore been in position nearly seven years without mishap, when, early in the morning of March 29th., 1905, it broke apart, at a time when the river was full of heavy running ice, and the water at extreme high water mark and rushing in a wild torrent.

A jam of ice piled up against the center pier of the bridge, causing the floating ice to crowd and sink to the bottom, almost completely damming the river. The ice crowded down, on to and around the pipe line, and when the pack started, nothing could have withstood the strain, so the pipe went with it.

Any water works man who has had experience with a direct pumpage system of water works, will appreciate the fact when I say that when this twelve inch pipe opened at both ends, there were doings at the pump station, and to the men in charge it was evident that something had been opened, and left open.

The pressure immediately dropped to but a few pounds, and the town was without water. It did not require much speculation to determine what had happened, so the gates at each end of the pipe line were closed, and the normal pressure quickly regained.

Examinations of the ruptured pipe line disclosed the fact that one of the lengths of pipe had broken in the joint, at a place where the current of the river had been strongest; and the broken pipe line had been carried down, far out of its original position, and until the ruptured ends were about fifteen feet apart.

How to best make repairs was the question that was up to the superintendent.

At one time I was convinced that the best plan was to pick up the broken ends, raise the pipe over scows, and

put in an additional length of pipe. At another time I was sure that the only right way was to procure divers, and scows, and work the pipe back to its original position, and then have a diver put on a special sleeve, and close the break, but I could not devise a way to hold the pipe from pulling out of the sleeve, if a heavy strain was put upon the line in the future, and again, bell divers are a necessity which ill befit the resources of a water works of moderate resources; and so "oft in the stilly night" I lay, and squirmed, and was brought to a realization of the fact that it is not the man behind the pick and shovel who does all of the work in a Water Works outfit.

The scheme which was finally adopted, and which worked admirably, came not as an inspiration to the writer, but as a recollection of methods employed by Mr. Ward, patentee of the pipe, when laying the line originally.

The shore ends of the pipe line were uncovered and made as free as possible from gravel or other material which might obstruct or hinder it from being drawn shoreward. The pipe was disconnected at the westerly end, where the ground is low and flat, and a heavy capstan with horses for power was anchored, and made fast to it with block and cable tackle. After two or three slight mishaps to the tackle and failures to start the heavy load, the pipe line moved, and once started came quite freely, each length being melted free with kerosene oil heaters, and disconnected as it came ashore.

After the westerly portion of the pipe had been taken from the water, it was necessary to employ a diver to make fast to the broken end of the easterly portion with a heavy cable about an inch and a half in diameter. The power was applied, but the pipe would not move, the cable being parted several times in the effort.

It was found upon further examination, that the pipe had rolled over a ledge of rock, and was jammed in such a manner that it was necessary to raise it out, and on to the ledge, which was done by means of a scow and pipe derrick.

Once free, there was no further difficulty in hauling the easterly half of the pipe line across to the west side

of the river, and disconnecting it as had been done with the first taken out.

The disconnected lengths were then carted to the high ground on the easterly side of the river, cleaned, coated with water proof metallic paint, and made ready to be put together again.

A tight wooden plug was fitted into the leading bell end to keep out gravel and other debris, a heavy wrought iron band was bolted back of the bell, and to this band were welded heavy iron draw bars, meeting in front of the center of the bell in a clevis to which was attached the cable reaching across to the capstan on the west shore. As soon as a joint was poured and caulked, the pipe was hauled into the water by means of the cable, and in this manner the pipe was again made continuous, and upon testing found to be tight.

The cost of repairs was comparatively small, and while it is perhaps but a matter of time and of similar conditions obtaining, before the pipe will be carried away again, it is believe to be good economy to pay for repairs rather than excavate a trench in the rock bottom of the river.

SOME PERSONAL EXPERIENCES.

L. N. Case.

The Secretary is getting anxious. He writes me under date of April 18th, to come to the rescue with a paper on personal experiences: Says the members do not answer his circular letter with any generosity, and that he has got to have enough of this kind of stuff to occupy one day of the convention or there will be a serious "break in the proceedings."

Now any kind of break to a water works man is a serious matter, and if we only knew before hand when and where they would occur it would materially lighten our labors.

The secretary warns us of this break in plenty of time for us to get out our picks and shovels and commence to dig; dig into our own memories and see if we cannot find something that will be of interest to the convention; something that will instruct or amuse you to the extent that you may not consider the time entirely wasted.

I am acting on the supposition that the secretary wants some of my experiences as a water works man; and that anything that may have happened to me as a soldier or as a citizen, a husband or a father, or in any other relation of life than that of selling water, is of no account and not wanted.

Of course I understand that most of the members have had experinece with meters: have sat and with watch in hand gazed on the circumlocution of the hands of the dial, and worried for fear they would tell an untruth. You have had fast meters and slow meters, and yet none of you I dare say have had a meter that would continuously and systematically register with no water passing through it.

That experinece has been mine; that is if the word of an honest intelligent citizen of Duluth is worth anything. He swore that three months previouslyl he had had the meter read by this department and had immediately shut off the water, and that of his own personal

knowledge it had not been turned on again; and yet there was an increased registration amounting to $30.00 which we were asking him to pay. "And do you mean to say" asked I "that your meter will operate and register without any water passing through it?" "I mean to say that no water has passed through that meter since it was read for me at the time I shut it off" he replied. "Now my friend," said I "if this is true, you have a piece of mechanism that is very valuable. It is what thousands of dollars and many lives have been spent to obtain, which is perpetual motion. I think his answer as he slammed my door, was, that I could go to the devil.

Another experience that I had that is by no means common: the registration of a meter at a laundry had long been unsatisfactory to my Assistant Secretary, and he finally confided his doubts to me. The meter had been examined, but not tested by the Inspector, and had been sealed and everything seemed to be all right. I ordered another meter placed in tandem with it which registered between 2 and 3 times that of the first. I then ordered it brought to the office and there discovered that a 5/8" dial was registering the water passing through this one inch meter. Calculation was made of the difference between what he should have paid for the past 6 years and what he did pay, amounting to about $600, and which Mr. Laundry man had to pay. This dial must have been attached at the factory.

And still another: suspecting that a certain laundry was beating us as to the quantity of water they were using, we discovered that in each month, along about the 20th, the proprietor would remove the clock work and sitting down to his sewing machine, and holding it against the revolving band, would turn the clock work backwards until the registration showed a quantity that his conscience would permit him to pay for, and his conscience was not very elastic.

Not long after I had another singular experience and one that bothered me considerably before I discovered the cause.

Our supply is with gravity pressure from a reservoir, which, at the location where this affair occurred amounted to 120 pounds.

One day I was called up by a business firm that had a fire extinguishing sprinkler system in their building and was asked what was the cause of the excessive water pressure at their place. I answered that there was none that from the fact that the reservoir was only 390 feet above the lake that 125 pounds was the most that could be obtained at the very lowest level.

My interlocutor was inclined to become indignant and said that the gauge on their fire system showed 160 pounds and he guessed he knew what he was talking about. My opinion at first was that something was wrong either with the gauge or the sprinkler system, but soon after when another firm shot the same information at me, I began to think some other cause was effecting these results.

Upon investigation I found that these systems were equipped with a check valve that permitted the flow of water and increase of pressures inwardly, but prevented their escape. About a block away was a stand pipe that supplied the track engines of a railway company. At its installaiton we had required a relief valve to be placed thereon, which had gotten out of order and was leaking. The man in charge, to prevent this, had closed the valve nearly shut, and the result was that the sudden stoppages in the flow of water when the engines discontinued their supplies produced rams in the mains, increasing temporarily the pressures to over 160 pounds. These increased pressures were of course communicated to the water in these sprinkler systems and of course remained there.

Neither the private company, of whom the city purchased the plant, nor did the City itself at first have any minimum meter rate. Soon after my employment as manager and in my initial study of the system and its operations, I discovered that there were on the rolls about 125 customers who were paying from 15 to 30 cents monthly for their supply. I immediately recom-

mended and had adopted a minimum monthly rate of 50 cents and thereupon these 125 true and loyal citizens began to make it hot for me. I was cited to appear before the Common Council and to show cause for this radical change in the rates.

Several of the Aldermen, desiring to pose as the poor man's friend, made eloquent speeches against the adoption of this rate, claiming it made a poor man pay for that which he did not have, ect., etc., etc.

When finally I was asked to explain I began with the assumption that I judged from the remarks of the Aldermen that it was the desire of the Council to protect and care for the interests of the poorer classes of our citizens; and, if so, that there was another class, not affected by the adoption of this rate that, as far as their conditions were concerned and their earnings, deserved our first sympathies.

The minimum flat rate then in force was $2.25 per quarter paid in advance or 75 cents a month. I called the Council's attention to the fact that this still poorer class, who were unable to purchase a meter, and who gave us no trouble and who required no attention except the writing of a receipt once in three months were forced to pay 75 cents for the same privileges that their richer neighbor obtained for 25 cents.

I explained how impossible it would be to operate a plant successfully and receive the small sum from each consumer of $3.00 per annum. I explained that our charges must be reasonable and harmonious and that this minimum rate would assist materially in reducing the cost of their less fortunate neighbors.

The council unanimously sustained my position, but there are quite a number of our consumers who have had it "in for me" ever since.

Upon those who are young in the business I would impress this truth: every result has a cause. At times it may appear to you that no explanation can account for certain accidents: I have heard at times that the breaking of a water main has been styled, pure deviltry,

especially when it seemed impossible to account for it with any known reasoning.

My friends, don't you believe it. Nature has no rewards or punishments, only consequences; and the construction of a water pipe, its placement in the ground and its use as a conductor of flowing water, are all subject to and are controlled by the laws of nature, and it is incumbent upon you, if you desire to make a success of your profession, to hunt out the cause of every condition that comes within your experiences.

It occurs to me, in indulging in these reminiscences of my long experience as a manager of a public plant, that there is nothing so common to us all as the fellow who wants a special privilege.

He comes in various guises. At one time, in a wheedling manner he tells you you're a good fellow, and that he will do you some time a similar favor: at another, conscious of his political pull and the possible power he possesses, he takes it for granted that he has but to express his wishes to see them immediately complied with: At still another he comes to you with the arrogance of wealth and social standing and looking down upon you as though he needed a powerful lenz to locate your existence, states in a cool and lordly manner what you are to do.

It has always been a pleasure to me to look these seekers after special privileges, square in the face and tell them they could not have them. The motto of equal rights to all and special privileges to none has always appealed to me as the only just way to conduct a public business, and the only way by which it could be made successful and satisfactory to all the people.

A certain bank president presented his check for payment of his rates the day after the time had expired in which discounts were allowed. This happened soon after I had assumed the duties of the office I now hold.

This regulation had been promulgated thoroughly and so that no one could by any possibility be ignorant of it. The clerk to whom he presented his check for the amount less the discount, tried to explain that he

could not receive it, but was browbeaten into silence by the manner and language of his lordship.

He, the clerk, finally came to me where I sat in an inner office and asked if I would come out and talk to the gentleman. As I approached he looked at me with his eyes half shut as though he considered it difficult to see me with his naked eye, and demanded that his payment, as presented, should be received. I calmly told him that this was impossible; that this rule necessarily was an iron rule inasmuch as all consumers were to be governed by it, that if one man could be permitted an additional day in which to make these payments then it would be only fair and right that all should enjoy the same privileges: and that the Board had established 12 days in which these payments could be made, which had been deemed amply sufficient for this purpose.

In response he roared out to me "If you intend to run this business in that jug handled style you'll make a dead failure of it" coupled with other opprobrious remarks.

When he stopped to get his breath, I leaned over towards him and sharply said: "If the success of this department depends upon treating you better than anybody else it can go straight to the devil," and turned and left him.

Now what was the result?

Several months after he was asked by a gentleman from Detroit, who had some business relations with him, how I was doing and what satisfaction I was giving, and he was actually effusive in the compliments he paid me.

I am aware gentlemen that there must necessarily be considerable egotism in the indulgence of reminiscenses and in the recounting of experiences, but I hope you will divest your minds of any thought that I desire to assume any such position, and that you may be able to draw a moral from some one of the experiences I have presented that will be of use to you in your daily lives.

STRIPPING RESERVOIR LAND; OR SOME METHOD USED FOR THE PREVENTION AND GROWTH OF ALGAE.

T. W. Davey.

Large sums of money have been expended for stripping reservoir land to prevent the growth of Algae which is a source of great annoyance on account of the offensive odor and taste which it imparts to the water: and also to the clogging of water mains by its adherence to the inside shell of the pipe.

Middletown, N. Y., has three reservoirs covering a combined area of 276 acres. They are impounding reservoirs and obtain their water from a few springs and the surrounding water shed. During the summer months large growths of Algae make their appearance and, realizing the evil effects of impure and unpalatable water on the health of the community, and appreciating the fact that a city supplying an abundance of pure water attracts population and manufacturing enterprises, the Board of Water Commissioners in 1899 decided to install a filtration plant. After fully investigating the various methods of filtration the Mechanical type of filters was decided upon, and subsequently a contract entered into with the Continental Filter Company of New York for a Combined pressure and gravity system, which was completed in May 1900.

As the summer months approached and the water attained its usual condition, due to the presence of Algae, impediment to filtration became at once apparent by the clogging of the filters necessitating them to be washed more frequently than usual. An effort was then made to deepen the shores of Monhagen reservoir by excavating and forming an embankment with slopes

protected with riprap, thus stripping an area of several acres of land. For about two years the shore protected with riprap was apparently clear, but after that time became as bad as before—except in places where the water remained four or five feet deep.

During the latter part of July and the first part of August, 1904, there was a very disagreeable odor and taste in the water that even the filters failed to remove. Prof. James M. Caird, Chemist, of Troy, N. Y., was called upon and after a thorough examination recommended the copper sulphate treatment, which was productive of good results in killing the Algae, especially the smaller specie. In Monhagen reservoir, the principal distributing reservoir and the one supplying the gravity filters, the amount of copper sulphate used was one part to 3,333,000 parts of water. Three days after treatment the Algae known as potamogeton (pond weed) began to come to the surface and floated to the shores.

Each year since 1904 the reservoirs have been treated with copper sulphate by our local Chemist, Mr. Irving C. Bull, with excellent results. Upon the recommendation of Mr. Bull, Highland reservoir was treated on June 1st, 1906, at the first appearance of Algae with the result that the water in that reservoir has been of excellent quality and remained so throughout the summer and up to the present time.

Monhagen reservoir was not treated until August 18th, 1906, some time after Algae first began to appear, consequently did not respond to the treatment as rapidly as Highland as will be seen by the following extract taken from the annual report of the Chemist for the year 1906;

"The growth of Algae in Monhagen reservoir was so great that a strong treatment was made necessary. The copper sulphate being applied at the rate of one part to 1,848,000 parts of water. The progress of the treatment was not rapid, about ten days having elapsed before any improvement was noticed. The water in this reservoir should have been treated fully seven weeks

earlier. I believe this fact was made evident to all who viewed the conditions at the time of treatment.

"It is not economical to permit reservoirs to get in the condition as was Monhagen. The expense of treatment is greater and the best results cannot be obtained."

DISCUSSION

SEC'Y DIVEN: I have a fellow *feeling for Bro. Davey*, as I have been in this boat myself, with a reservoir which was thoroughly stripped, but nevertheless algae got into it. The reservoir was a reserve supply. When we tried to filter the water it was found impossible to do it, on account of the excessive algae growths.

SOME EXPERIENCES IN THE MANAGEMENT OF A SMALL WATER WORKS.

Howard Williams.

I believe that I represent one of the smallest water plants represented in this association.

As a general thing I do not approve of knocking but I have a grievance and if I am allowed the floor I would like to do a little knocking and see if I can get some of the other little fellows to knocking also.

The first meeting of this association which I attended was held in Minneapolis in 1894. Although I did not have an opportunity to attend another meeting until five years ago when you met in Chicago I have always been interested in the papers which have been read by the members of this association.

We have been told how they filter the water at St. Louis; how although the city of New York has already spent millions of dollars in getting a supply of water they are still, like Oliver Twist, asking for more, how the great earthquake of 1906 put the water works of San Francisco out of commission and how our brother from Chicago found that some of their citizens were stealing more water from the city mains in a single month than many of our small water plants could pump in a year. All this we have been told followed by dozens of papers on technical subjects which while very interesting to listen to can be of no possible use to the average Superintendent of a small plant while the every day trials and perplexities of the little fellow are seldom spoken of.

Now I do not wish to be misunderstood in this matter. I have no objections to the managers of a large plant telling their experiences and taking up all the time they wish. Indeed these meetings would be very tame affairs if they did not put their shoulders to the wheel and push.

But it is the little fellows that I complain of and as

I am one of the little fellows myself I feel that I have a right to complain. I tell you what brothers you are not doing your duty. You are not getting your money's worth as long as you come to these meetings and persist in taking a back seat.

I understand that this association was organized for the express purpose of bringing together the water works men both large and small from all parts of the country to discuss matters in which they are mutually interested, but unless we little fellows will wake up and take more active part in the proceedings there will soon be no place for us in these meetings.

I know that some of us at least are apt to think that our little experiences can be of no interest to the men who have experiences that will permit them to write the class of papers to which we have been listening, but in this matter I believe that you are mistaken. I will even go farther and say that I believe that we can teach these big brothers something if we will only make the attempt. There is not a man in this room but has some experience during the year that would be of interest to the members of this association if he would bring it before the meeting.

Now brothers get busy and talk. It does not matter so much what you talk about as it does that you make a start. If you think that I, a comparatively unknown and obscure member have been too fresh in starting out in this way say so. I have been in the water business too long to have my feelings hurt by such a trifle as that.

Probably there are very few of the "big fellows", if you will allow the expression, who realize what is expected of the Superintendent of water works in a small city.

First he must be a man of tact. Whether the plant is owned by the city or a private corporation he is generally the only visible head. He is the man who must deal with the water takers, see that they pay their water rates promptly and that they are satisfied with the service.

He must personally oversee the installing of new machinery, laying of water mains and repairs.

He must be able and willing at a moments notice to jump in and fill any position from bookkeeper to shoveler. He must be ever on the alert to get better service from his plant.

If the plant which he represents is owned by the city his duties may be still more manifold. To illustrate I will tell you of some of the things that I have done during the past year. To begin with I have sometimes been saddled with the title of Superintendent of Water Works and Sewers but I repudiate the last part of the title. I am afraid that if a new branch is added to my title for every new line of work that I am expected to take up, the burden would be greater than I could bear.

Early last spring a bridge over the river needed rebuilding and as this came under the supervision of the Board of Public Works, they thought that I should see that the work went forward. I did it, laying out the work and making a pattern for every angle that was needed.

When this was completed a stone culvert under one of our principal streets collapsed and our Common Council ordered that it be immediately replaced with a solid cement arch and that the work be done under the supervision of the Superintendent of Water Works.

Our Mayor, who by the way would make a rattling Superintendent of Water Works, asked if I would undertake it and because he used tact in the asking I agreed to do so.

He informed me there was $300.00 in the fund to do the work with and asked if that would be enough. I told him it would not and that I could not make an estimate until we got to the bottom and saw what shape the old foundation was in. I was told to go ahead and be sure the work was strong. I was also informed that the work must be completed within thirty days so as not to interfere with the dummy line which would commence operations at that time.

These were absolutely all the instruction I had in regard to the work. No plans or specifications whatever. The old culvert was fourteen feet below the street level on a pile foundation and had settled five feet into the mud. The new culvert when completed was seventy feet long five feet wide and seven feet high in the clear. Walls eighteen inches thick with a retaining wall and wings at each end fourteen feet high. It was completed within the required time and cost—Well it used up the $300.00.

During the same time I repaired a section of dock at the entrance to the harbor where a hand ferry is operated to carry teams over the river. When this was completed there were some repairs needed on our intake pipes which extend into Lake Michigan. For this work we have a small steam scow that comes under U. S. Marine law and when the boat is in commission I act as pilot. While the work on the lake was in progress I was expected to put on a diving suit and go down to inspect the work.

This work lasted until well into August but in the meantime I had kept an eye on a contractor who was building a large cement building for the storage of coal at the pumping station, laid one half mile of six inch water pipe and dug up and relaid 200 feet of sewer pipe besides attending to the usual odd jobs that turn up during the spring. At this time the young lady who had attended to the office work for several years saw fit to marry and I was obliged to look for a new bookkeeper. I am held personally responsible for the office and collections and for the next three months I was obliged to keep considerable more than one eye on this department.

When the work on the lake was completed I laid another half mile of water pipe, dug up and repaired 300 feet of sewer on a paved street, repaved the street and as it was getting late got things in shape for winter. We have about 200 meters in use. I read them myself and when repairs are necessary I do that also. To fill in idle moments I occasionally give the engineers a hand

at the pumping station. I forgot to state that I am also a member of our fire department.

We have in our system 18 miles of mains four miles of which are of wood that has seen twenty-five years service. Two Holly Pumps, 1300 water takers.

I do not wish to monopolize too much of your time and will only take time to tell you of two or three things that have both puzzled and interested me. I have had some experiences with meters during the past few years which while they might have been easy for an older meter man than myself, were puzzlers to me for some time. Several years ago I set a meter on one of the hotels at a resort about one and one half miles from the pumping station. A week after setting I stopped to see if it was working all right and found that it registered less than when it was set.

As the meter was set right and there did not seem to be any indications that it had been tampered with I concluded that I had misread the meter in the first place and merely took the new reading as correct. The next week the reading was still less and things began to look serious. I took the meter out looked it over and finding it all right replaced it taking the prectution to cover it with a strong plank box secured with a padlock. Two days later the reading was still less. I took the meter out and replaced it with another and, the day following the hotel had another bill against us.

Although this was a conundrum the explanation was simple when once I found the key.

The main was a new four inch cast iron pipe nearly one mile long from where it connected to a larger pipe. In a hollow twenty feet or more below where the meter was set was a fire hydrant. As there was very little water being used on the line the coating on the pipe imparted a disagreeable taste to the water and I had flushed the hydrant every time I was in the vicinity, which was nearly every day. I found that the water coming into the pipe was not sufficient to supply the hydrant and also keep the pipes full where they went

up over the hills. Consequently whenever the hydrant was flushed every opening on the hills would suck in air causing the meter to run backward much faster than it would go forward with ordinary use. As the road to the hotel led past the hydrant I had always flushed the hydrant first and read the meter afterward. A good check valve was placed in front of the meter and I had no further trouble.

We have had considerable trouble with sand in our mains which has made it difficult to get satisfactory results from meters in some sections of the city. However we have succeeded in shutting off the inflow of sand from the lake and expect to have much less trouble from this cause in the future. I have had several cases where the meter would apparently take a jump either forward or backward and where the explanation was not easy to find. However I make it a practice to place a check valve either in front or behind a meter that is inclined to work for the other fellow and it generally corrects the trouble. I have had but one case where a meter has been tampered with, and in that case the party was trying to satisfy his curiosity as to how the thing worked. As he got the meter together wrong it shut off his supply of water and he was obliged to come to me for help and own up to what he had done.

Not long ago I had an experience in running a lead joint where the pipe was partly submerged. I do not claim that the idea was original with me and I do not know at this time where I heard of its being done in this way. However, as even a chesnut may be of interest to some one who has run up against such a proposition, I will tell you how I managed it. As I have said this pipe was partly submerged and as it came under one of the main timbers of a bridge it was impossible to raise it more than one half of its diameter out of the water. After raising the pipe as far as possible the joint was yarned in the usual manner. As a clay roll would not stick in the water and I had no asbestos roll I used a piece of twisted hemp packing instead. The upper side above the water line was pieced

out with clay with the usual pouring hole on top. On one side just above the water line I made an extra vent. Before pouring the lead I placed a small quantity of oil in the upper opening and the lead was then poured in the usual manner. The oil prevented the hot lead from coming in contact with the water and as the lead was poured it forced the oil down which in turn forced the water out of the vent on the side of the pipe. The result was very satisfactory leaving the joint well filled and ready for calking.

A FEW EXPERIENCES ON THE EXAMINATION OF WATER WORKS ACCOUNTS AND MANAGEMENT.

John F. J. Mulhall.

In the particular cases mentioned, both Treasurers were exceptionally able men in other directions,—one being a Bank President and the other Town Treasurer for several years.

The first case was that of a Water Company which had been running for about eight years, supplying a population of 20,000 with a capitalization of $150,000.

The Treasurer's reports were submitted annually, each successive report showing a small profit, notwithstanding a large increase in the number of consumers, including a few very large consumers of water.

A practical water works man, both as to construction, management and operation was added to the Board of Directors, who was at a loss to understand why the profits were not materially greater; whereupon it was decided to have an examination made, which received the hearty concurrence of the Treasurer.

On making a hasty examination, I found much to my surprise, that the accounts had been kept in a manner, practically showing the receipts on one side and the disbursements upon the other, without making any differentiation between cash received from the sale of water, supplies, notes issued, etc.; nor whether the payments were made for Capital Account, maturing notes, operation and maintenance, or fixed charges, etc.

It was absolutely necessary to re-write the accounts from the beginning, the final result showing that after payment of all operation, maintenance and fixed charges, the plant was earning between 3 and 4 per cent. on the Capital Stock.

The other case where the Town Treasurer was also Treasurer of the Water Works, was somewhat analagous to the foregoing, with the exception that he

had merged the receipts and expenses of all the Town departments together, including the water works.

The Treasurer frankly stated he could not tell from his accounts the amounts received from the sale of water; nor the payments made on account of the works.

The property owners had been assessed annually (included in the Tax levy) to take care of the sinking fund requirements of the Water Works, amounting to from $2000. to $3000. annually.

In this case it was necessary to arange a complete system of account books and forms, covering the financial and operating departments of the works.

After the books were written up, the net earnings of the works, not only took care of its own sinking fund requirements, but also accumulated a surplus.

GENERAL ERRORS IN ACCOUNTING AND MANAGEMENT.

Repairs, renewals and depreciation.

A common error is to find items of repairs or renewals of original parts of a plant, especially when they amount to a considerable item, charged direct to a capital account,—Construction. All such items are properly chargeable to "Repairs" and finally charged out of Profit and Loss account.

For all items of renewals of a unit or units of a plant, such as the installation of a new boiler, pump, substitution of a new line of street piping, in lieu of an old boiler, pump or pipe line of same capacity, which have been discarded, such items should be charged direct to Renewal account. If however, the new installations are improvements and of greater capacities than the old ones, it is fair to change the excess costs less salvage, direct to capital account,—Construction.

If there has been a Depreciation account opened of sufficient amount to cover all actual renewals and a fair allowance for the invisible depreciation which is always accruing in plants, then this item of Renewals should be charged into Depreciation account. If other-

wise, it should be charged direct to Profit and Loss account.

The subject of Depreciation has so many ramifications, no two plants being exactly alike as to construction, location, source of supply, etc., etc., that I have referred briefly to the fundamentals.

Pump slippage while more in the line of the management of a plant, nevertheless the results accruing therefrom are strictly financial, — the cost of the fuel force, etc., necessary to operate same being one of the overlooked bung-holes in water works finance. Pumps should be kept in repair at all times so as to keep up as far as possible their normal efficiency,—occasional tests being made of same. The president of the association, Mr. Maury read a valuable paper on this subject at last year's meeting, wherein he stated he had found "pump slippage" ranging (as I now recall) from 12 to 85 per cent. on some tests which he had made.

RECORDS OF THE PHYSICAL PROPERTIES.

A large number of water works fail to keep any complete record either by plan or books, of the kind, size, length, location, etc., of the pipes, valves and hydrants, which are buried in the ground; nor of the dimensions, capacities, method of constructon, etc., of the reservoirs, standpipes, boilers, pumps, filters, etc. In such cases, this information can be secured only from the "memory" of the Superintendent or Foreman; or from the original contracts for building some of the structures, if any. If the contracts are in existence, they are generally lost or misplaced in the office files.

The life of cast iron pipe under normal conditions not having yet been determined, it can readily be seen that a water works system will easily outlive two or three superintendents who were alone possessors of this information and in the great majority of cases by "memory or guess work" only. Furthermore, the necessity of having this information immediately available in case of breaks in the system, where damages resulting

therefrom might amount to 100 times the cost (in case the superintendent was either absent or compelled to stay at home by reason of illness) of getting this data together, would appear to be sufficient reason, for having both plan and book records covering same; or at least plans.

Classification of accounts is another subject which appears to have no consideration in a large number of water works. For all large systems, the disbursements at least should be separated into units, such as: Pumping station, distribution, fixed charges, general expenses. construction,—these headings being still further subdivided, showing the details under each head.

The receipts, "Water" should be sub-divided into meters, fixtures, public hydrants, private hydrants, flushing sewers, etc.

A classification chart in the hands of the accountant or bookkeeper giving the details of the items chargeable to the ledger accounts and sub-divisions thereof, would economize not only in time but materially assist in the accounting department.

For small works the accounting can be considerably condensed, if desired, by having ledger headings Water (Fixtures, Meters, Misc'l) Meter Rentals, if any; Expense, Repairs, Renewals, Fuel, Salaries and Wages, Taxes and Interest.

A WHEEL PUMP.

H. F. Dunham.

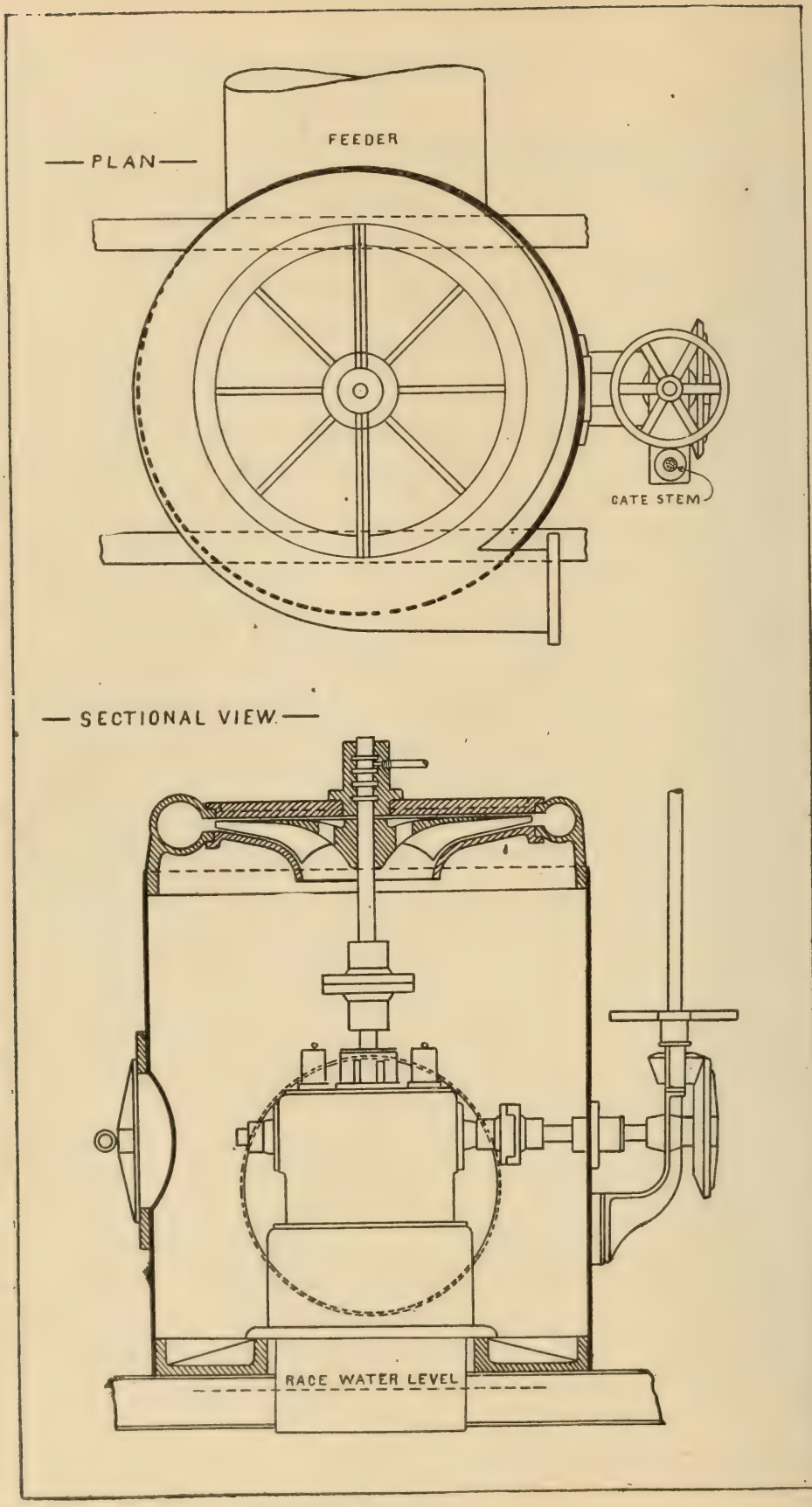
The request from our secretary for a description of simple operations to be comprised in a thousand words or less is a good one because easy problems are often solved in different ways by different members. And further interest is awakened when two or more members determine similar questions by like methods.

Many years ago, in the '80's in fact, the writer designed a combination of a water wheel pump by which water under pressure from a public supply should do the work necessary to lift sewage to a required elevation. The water was to be held under pressure constantly and returned to the water-works pumps without being in any way polluted. This made a simple and compact design but another plan for disposal of the sewage was finally adopted and the proposed unit was not built.

Recently it was required to deliver water from a river offering the advantages of 11 feet head, to a sedimentation reservoir at an elevation corresponding, with friction included, to about 20 feet. Of the numerous possible and attractive methods, the most modern and electrical would be to set a water wheel to run a generator to run a motor to run a pump to run the water to the said reservoir—with a maximum times a maximum coefficient, etc., of uesful effect from the wheel.

But it occasionally happens that too many translations of energy demand too much attention to the translators and in this case it was desired to reduce labor and attention to a low limit.

A vertical turbine wheel was associated with a centrifugal pump with dimensions, head, lift and speed favorably related. The body of the pump formed the top of the wheel case which was not increased above the usual height. A feeder was provided large enough to convey the water required to run the wheel and to supply the pump. The rotor of the pump was connected to the wheel shaft by its own shaft which terminated above


— PLAN —
FEEDER
GATE STEM
— SECTIONAL VIEW —
RACE WATER LEVEL

the wheel case and above the side of the pump as well in a babbitted thrust bearing. The wheel shaft was supported upon the usual wooden step. The sides of the pump were made in two pieces so that each can be unbolted—one from inside the wheel case—and removed, leaving the volute riveted to the wheel case. Through the opening thus provided the rotor of the pump and the wheel itself can be easily removed if necessary. A small pipe from the discharge conveys water under pressure to the thrust bearing for lubrication. No oil is used. The outfit has been in operation about a year. The wheel is provided with a gate. Should they wish to stop the flow of water to the reservoir they will close the gate.

THE OPERATION OF PUMPS WHILE SUBMERGED ON ACCOUNT OF EXCESSIVE FLOOD.

By E. Forrest Williams.

During the extreme high floods of the winter of 1907, the water at Duequense, Pennsylvania registered 4 feet above any previous record, and the pumping plant of the water department was flooded, the pumps being covered to a depth of several feet. The boiler room also being flooded and fires put out; made it necessary to operate the plant by steam obtained from other sources and with the pumps under water. The pump in question is a one and one-half million gallon per 24 hours Compound Duplex Condensing engine, and during the flooding it was worked with free exhaust and under 25 feet of water. This was accomplished in the following manner: Two large locomotives were placed as near to the pump station as possible, the distance being about 300 feet from the pump, and connected with the steam line in the building by two 2″ lines; these steam lines were suspended over the water by wire cables; the lines were connected to the steam line at the top of one of the regular boilers, from which a 5″ steam line ran down through 30 feet of water to the pumps. The engineer, Charles E. Zimmerman, constructed a raft and anchored it over the engine, and from this raft he operated the throttle valve; steam was turned on, and after the engine cleared itself of condensed steam, it started up and pumped 540 gallons of water per minute, against a head of 423 feet; keeping up the supply of water for the city, and giving ample fire protection during the time of high water. The pumps were operated in this manner for thirty-six hours.

We consider this a unique experience in the operation of a pumping plant, and the sucessful overcoming of an apparently insurmountable condition.

DISCUSSION

A MEMBER: I have had some little experience in that line myself on the Ohio River. We had a very heavy flood and we opened a hole to clean the suction, and the water forced a way out so that the pit was filled with 30 or 40 feet of water. We had to have the water in the city. Our boilers were on high ground. It was a risky business.

CONNECTIONS FROM PUBLIC WATER SUPPLY FOR PRIVATE FIRE PROTECTION SERVICE.

A. W. Hardy.

For several years a subject of considerable interest to water works officials has been before members of this association concerning questions relating to public water supply connections for private fire protection service. This problem has attained more importance in recent years owing to the large number and increasing frequency of demands for this service to be used in connection with automatic sprinkler equipments.

Without becoming a party to the discussion in relation thereto at this time, I have thought possibly a brief statement concerning the functions of automatic sprinklers and the extent which the installation of sprinkler equipments has reached, might be of interest to members of this association.

I have been intimately connected with this special work for the last fifteen years in devising and installing sprinkler equipments, as an insurance inspector and as an insurance underwriter, having, I believe due appreciation of the features which water works officials wish to establish and safeguard, and also the objects which particularly involve insurance interests.

The questions involved have been the subject of considerable committee work and some reports to this Association, but no unification of interests in their practical application has yet been reached. The matter assumes considerable importance, because this kind of protection for private properties is increasing very rapidly, and includes nearly all kinds of manufacturing industries and plants, more or less isolated as to other surrounding buildings, and also mercantile establishments both within and without the limits of the congested districts in our cities.

It is a very difficult matter to obtain accurate information as to the number of different, distinct, indi-

vidual properties which are brought into and added to this class of protected risks each year, but I think I am well within the limit when I say that 600 such individual risks will be equipped with automatic sprinklers within the limits of the United States during the present calendar year, covering insurable values exceeding $100-000,000. In not all of these, however, will there be involved the question of a connection with a public water supply; for some of these risks, no such supply is available; but probably sixty to seventy-five per cent. of them will wish to depend in part upon such a connection.

Rules governing the installation of automatic sprinklers require every standard equipment to have at least two sources of water supply, each independent of the other to the extent that one shall in no way be impaired or involved by an accidental or a necessary interruption of the other; both of these two supply sources to be so arranged that they may be, and shall be, automatic in their service, to, and through, the sprinkler equipment.

On the automatic feature rests largely the principle that has given rise to the differences that exist between water works officials and insurance interests, which interests are at variance on some matters of detail only. On the basic principle underlying the entire matter, the interests of both parties rest in harmony: to secure the prevention of fire waste.

The number of independent, distinct sprinkler equipped properties in the United States is probably not less than 10,000, the majority of which are served as to one of the two required water supplies by a connection from some available public water supply.

The questions involved in relation thereto are therefore, in view of their extent and application, presumably of considerable interest to water works officials as they also are to property interests and to insurance interests.

The development of the science of fire protection and fire protection engineering, appears to be lodged

with fire insurance companies, and through them these problems should naturally reach a solution.

The evolution of fire protection by sprinkler equipments is due in part to commercial rivalry between the sellers and the buyers of automatic sprinklers, and to refinements which are the result of experience and which have crystalized into rules defining and regulating the manner of the installation of sprinklers as required by insurance companies, who ultimately but indirectly pay for them in the lower rates of insurance premiums based thereon.

For this latter reason sprinkler equipments are invariably installed in accordance with requirements of insurance interests, by which this class of fire protection has been made the subject of close and careful study, and are subject by contract between the seller and the buyer to the inspection and approval of insurance interests, whose engineers in this respect act in accordance with the functions of all true engineers, as arbiters of the quality of the goods and the execution of the contract. It is an essential rule that water supplies provided for and conducted to sprinkler systems may not be diverted to, nor used for, any other purpose, and it is a part of the insurance inspector's duty before an approval of the sprinkler equipment issues to know that this rule is observed; for the integrity of the equipment for its specific purpose requires that it must not be deprived of its essential element.

A fundamental element in their value for fire protection requires that the sprinkler heads, as they are called, shall be so distributed and located, that no space or area throughout the protected building shall be left beyond the "field" which may be covered by the operation of the sprinkler. The automatic principle, supported by the proper water supply, and certainty of operation in the event of fire, is intended to effectually control or extinguish the fire before it passes the stage of an incipient blaze; to extinguish the fire at the stage when a pail full of water, so to speak, is efficient and effective.

The sprinkler equipment in a building, must by its system of piping, and the distribution and location of the sprinklers reach every portion thereof, and only those sprinklers that are within the zone of a certain degree of heat generated by the fire, will open and operate; no water will be delivered elsewhere; hence it follows that sprinkler systems should be more effective and more economical of water demands in the event of a fire, than is possible for the best organized and most efficient public fire department .

It is not always possible, however, to confine the demands made by some fires within the limits indicated above, and it is to meet extreme and sometimes unavoidable conditions that a larger volume of water supply is required to be available than would be necesary if theoretical conditions could always be realized.

Pressure and volume in the matter of water supply are each important factors in the efficiency of sprinkler systems. Of these two elements, pressure is the first essential in the realization of the theoretical conditions for the control and extinguishment of an incipient blaze. Volume is the second but equally important essential. Ideal conditions include both of these essentials in every sprinkler equipment: high pressure initial supply, supported by sustained volume capacity, preferably also at high pressure, but necessarily at effective pressure.

It is the aim of every intelligent fire protection engineer not only to provide suitable and adequate water supplies when prescribing for or designing a sprinkler equipment, but to deliver those supplies at the sprinkler nozzle with the smallest possible frictional loss, and to realize to the utmost every pound of available pressure at the point of delivery. Any arrangement of piping or any devices introduced into the system of piping which can obstruct the freest possible flow of water therein detract by so much from the maximum efficiency of the sprinkler system by reducing its fires extinguishing power and minimizing its value for its specific and important purpose.

Hence the objection which the insurance engineers

have to meters and to unnecessary valves in connections for fire service, and particularly for sprinkler supply.

There is a live controversy at the present time between water works officials and insurance engineers over this question of meters. I believe both parties thereto will be united on some ground satisfactory to each, and on which the interests of both will be duly conserved; the growing importance of the question involved will make it necessary to do so.

The question at large as to the proper basis of charge for such service as private fire protection interests may derive from public water supply connections, it seems to me is fairly stated in a paper by Mr. Joseph Torrence Miller before this convention last year, and to be found on page 397 of last year's Proceedings. The paper referred to suggests the wisdom of a change in the methods and practice now common for distributing or assessing the cost of such service, and the remuneration to which the water department is entitled.

It is manifestly fair that the beneficiary shall pay a fair price for service rendered and that the benefactor shall be reimbursed for the cost which the furnishing of this service entails. But while the service rendered in cases of this kind is primarily to the individual, it is also in its essential nature a service in which the industrial and material welfare of the entire community participates; and the cost thereof should, in my opinion, not be assessed wholly against the individual or concern, nor assessed arbitrarily at all.

I believe a closer relationship between water works officials and insurance representatives and a better understanding by water works superintendents as to the elements and functions of sprinkler systems, including a more definite understanding in individual cases of the plan and arrangement of sprinkler equipments, will help greatly in harmonizing the views of all parties at interest, and will in a great measure eliminate the apparent necessity for requiring meters in such service connections. If there should be some cases where there may seem to be cause for requiring some special safe-

guard, I suggest that proper provision be made when service connections are laid that shall permit a pitometer test to be made at any time, and which can be made without previous notice to the customer.

As a member of this Association, a representative Association of water works officials having charge of the interests of an important public service, and jurisdiction over a wide territory, and also as an active participant in insurance interests involved, I hope and believe that an interested and earnest committee can suggest some plan whereby water works and insurance interests can be united, and under which each can cooperate with and support the other in the matter of physical conditions which should surround and attend such service connections.

RATES AND REGULATIONS FOR PRIVATE FIRE PROTECTION IN ATLANTA, GEORGIA.

Park Woodward.

These Rules have met with the approval of the Southeastern Tariff Association, and the Underwriters in Atlanta. And are sent, thinking possibly they may be of interest to other water works managers, who have to contend with this question.

WATER FOR FIRE PROTECTION

Water for fire protection shall not be introduced into any premises without application of the property owner having been first made to the Water Works Office and granted officially.

Water for fire protection shall consist of the following systems and be governed by the rules and regulations, as prescribed for each class of service.

(Class 1.)

DOMESTIC AND FIRE HYDRANT SERVICE

Combination domestic and fire hydrant service shall consist of a pipe line with a meter on by-pass of suitable size for the domestic service required. A valve of the same diameter of the pipe shall be placed in the line and be closed and sealed, so as to divert all water through the meter. This is the only class of fire service on which a tap will be allowed for domestic use. The seal on the closed valve is not to be broken only in the case of actual fire. When seal is broken the Water Department shall be notified in writing at once and the valve will be resealed by the Department.

(Class 2.)

FIRE HYDRANT SERVICE

Fire hydrant service shall consist of a pipe line with fire hydrants on same, the fire hydrant to be of the same size hose thread and operating nut as the City hydrant. All hydrants to be closed and sealed and opened only in case of actual fire. When seal is broken on any hydrant, the Water Department must be notified in writing at once, and the hydrants will be resealed by the Department. (See detector meter.)

(Class 3.)

STAND PIPE SERVICE

Stand pipe service shall consist of a pipe line with hose connections smaller than that of the standard 2½ inch hose as used by the City. All hose valves to be closed and sealed and opened only in case of actual fire. When the seal is broken the Water Department shall be notified in writing at once and valves will be resealed by Department. (See detector meter.)

(Class 4.)

AUTOMATIC SPRINKLER SERVICE

Automatic sprinkler service shall consist of a pipe line equipped with all

the necessary appliances, as required by the insurance companies, water to be supplied either direct to tank or a combination of both. Valve on by-pass to fill tank shall be closed and sealed. Seal to be broken only by an employee of the Water Department who will fill tank and reseal valves, which will be done upon request at the Water Works Office. (See detector meter.)

(Class 5.)

AUTOMATIC SPRINKLER AND FIRE HYDRANT SERVICE COMBINED.

Automatic sprinkler and fire hydrant service combined shall consist of a pipe line supplying both automatic sprinkler and fire hydrants. The rules governing class 2, (Fire Hydrant Service), and class 4 (Automatic Sprinkler Service), shall apply to this service. See detector meter.

DETECTOR METER.

Except in class 1 seals will not be required on classes 2, 3, 4 and 5, when an improved Detector Meter is placed in the line.

DRAIN VALVES.

All drain valves on any of the above classes of services are to be closed and sealed. When broken, Water Office shall be notified in writing at once, when same will be resealed.

REPORT OF INSTALLATION

Water will not be turned into any fire service until the company making same has filled and signed the blank installation report furnished by the Water Department.

REGULATIONS AND PENALTIES

The above classes of fire service for the protection and benefit of the property owner, for which the city does not receive compensation. When the seal on any of the above class of services is found broken and the Water Department not notified of same, the offending party shall be subject to a fine in the discretion of the Board of Water Commissioners. Any abuse or illegal connection for the use of water through these services shall forfeit the right of such services for fire protection, and the Board of Water Commissioners in their discretion have the power to require all such service provided with a meter, to be put in at any time, as said Board may in each case prescribe, and to make any change or just and reasonable requirements as good service may from time to time require in each instance, either as to said meter or as any other part of said appliances pertaining to the same.

(16.) The parties having connections used for fire protection can test their fire apparatus at any time under the following conditions.

1st. Notice to be given at the Water Office that such test is desired when date and hour will be fixed when test can be made.

2nd. When test of fire service is made by the duly authorized insurance representative or insurance inspector, no permit will be required to break the seals, but in each instance the Water Department shall be notified in writing at once, and the valve will be resealed by the department. This notice must be made by the insurance inspector or representative.

(17.) The expense of tapping the mains, making connections, testing completed work, placing valves, meters, or any other protective device that the Board of Water Commissioners may deem necessary to prevent the illegal use of water, must in all cases be borne by the owner of the property benefited. All connections from the city mains to the property line must be made by the authorized employees of the Water Department, and all piping, valves, hydrants and connections to said fire service inspected and approved by the Water Department before the water is turned into said service.

Adopted by the Board of Water Commissioners, January 26th, 1907.

Atlanta, Ga. .....190....

To the Honorable Board of Water Commissioners:

Gentlemen:—I have this day completed the Fire Service for .....

owner of property on.....St.

.....side, between.....St.

and.....St. and the same is ready for test.

Class of service.....

Size of street connections.....

Size and make of pipe.....

Number fire hydrants.....Size.....

Make.....

Number stand pipes.....Size.....Size

hose valve openings.....

Number sprinkler heads.....Make.....

Tank capacity in gallons.....Size.....

Size by-pass valve to fill tank.....Make.....

Location .....

.....

Number drain pipes.....Size.....

Location drain valves.....

.....

.....

Private valve cutting off street supply, size.....

Make.....

Location .....

.....

.....

I certify that the above is correct and all work done under the rules and regulations as required by the Board of Water Commissioners.

.....

Signature.....

Engineer or Plumber

Place of Business.....

NOTE.—**Water will not be turned on until this report is made out in detail, and filed at the Water Works Office.**

APPLICATION FOR FIRE SERVICE.

Atlanta, Ga. .....**190**....

To the Honorable Board of Water Commissioners:

Gentlemen:—I desire to have made a.....
inch Tap for Fire Service at my property No.....
.....St., on the.....side,
between.....St. and.....St.
Class of Service.....
Contracting Engineer or Plumber.....
Place of business.....
Remarks: .....
.....
.....

I agree to abide by the following rules and regulations:

Signature.....
Owner of property

SPECIAL FIRE PROTECTION RATES AND REGULATIONS, ELMIRA, N. Y.

J. M. Diven.

After reviewing the schedule of rates and the regulations established at Atlanta, Ga., for special or private fire protection concluded to give, as a contrast or variation, those in force at Elmira, N. Y., which Rates and Regulations were established by the writer.

One of the reasons for doing this is that one is a Municipally owned plant, the other a private company. The intention at Elmira was to protect the company's customers, and not to charge them for the fire protection as such.

The object of the by-pass and small meter was to facilitate inspection. The method of inspection was to shut off the water at the indicator-post valve and observe the meter. If water was leaking, or being used from the Fire Protection Supply, it would immediately show on the dial of the "inspection meter". The instructions to the inspectors was that when they found water running while the indicator-post valve was closed, to leave the valve closed and immediately notify the owners that it was closed and that repairs would have to be made before it would be turned on.

The insurance people could make no reasonable objection to this plan, as the automatic principal was in no way interfered with, except when the valve was closed for inspection. This was only for a few minutes at a time, and then when the attendant or inspector was at the valve, and ready to turn it on at short notice.

There was, of course, absence of "protection" while the water was off, but as stated above, that was only for a few minutes and then while a man was at the valve. There was not during that time "automatic" protection; but the water works are entitled to some protection as well as the insurance people. The inspections were made in the day time, when a fire could not get much start without being detected; and a very few seconds would be time enough to again turn on the water.

No notice was given at the mill when the water was to be turned off for inspection, as it was not suposed to in any way interfere with the work of the mill or factory. Should there be any interference with the factory supply it would be quite evident that such supply was being taken from the fire line, and not from the metered factory supply—this being contrary to the agreement could not be called a fault on the part of the water works.

Now the insurance people will object to the plan of leaving the water off when "leakage" is discovered; but do they demand that we shall allow water to run to waste, or, to be more plain in our language, that we shall allow the stealing of water, that they may be protected? Such a demand would be unreasonable—for, as stated above, we are entitled to some protection.

The inspectors were supposed to use some discretion, and if the "leak" was small—or even if it was an *evident* leak—they would give notice and time would be allowed to make repairs; but the service was on the "follow up" inspection list, and if the repairs had not been made at the time of the second inspection, it was considered right and reasonable to stop the service, and protection, till they were made. And at times it was found necessary to do this, for the repairs would not be made so long as the water was left on and the protection was being given.

The above devise is one devised by Past President, L. N. Case, (see paper by him in the proceedings of the 24th annual convention, page 425).

ELMIRA WATER, LIGHT AND RAILROAD COMPANY.

Application for Private Fire Line or Sprinkler Service.

I hereby apply to the Elmira Water, Light and Railroad Company for a .....inch Fire Service from its mains in.....Street, for fire protection to my.....at No. .....Street, and agree to the following rates, rules and regulations of the said Elmira Water, Light and Railroad Company for the control of such services.

RATES.

For a six inch fire or sprinkler service	$75.00 per year
For a four inch fire or sprinkler service	50.00 per year
For a three inch fire or sprinkler service	35.00 per year
For a two inch fire or sprinkler service	25.00 per year

For the above rates the use of water for factory or general use on the premises will be allowed as follows, viz:

With a six inch service	1,000,000 gallons per year.
With a four inch service	750,000 gallons per year.
With a three inch service	475,000 gallons per year.
With a two inch service	400,000 gallons per year.

RULES AND REGULATIONS FOR PRIVATE FIRE SERVICES.

No private fire or sprinkler service will be run into a building or suplied with water unless water is used on the premises for general purposes.

Private fire or sprinkler services shall be entirely separate from the general supply or other services, and shall be used exclusively for the extinguishing of fires.

Private fire or sprinkler services shall be provided with an Indicator Post Valve, of a make and pattern to be approved by the said Elmira Water, Light and Railroad Company, at the curb line, or at such other place as shall be agreed upon by the said Company.

Private fire or sprinkler services shall have a by-pass around the indicator post valve, or some other valve provided for the purpose and located at such place as the Company may designate. This by-pass to have a small water meter attached and placed in a suitable pit or other convenient place for reading and repairing it, and where it will be at all times accessible to the inspectors of the said Company, for the purpose of testing the fire sprinkler services for leaks or improper use of water.

No tap or water connection shall be allowed on a private fire or sprinkler service for use except for extinguishing fire.

The agents or servants of the said Company shall be permitted at all reasonable times to inspect the fire or sprinkler services, and all other water services or connections on the premises, and may, if it deem it necessary, put seals on any valve, hydrant, or other outlet from the fire or sprinkler service.

Upon the discovery of any breach of these rules and regulations the said Elmira Water, Light and Railroad Company may terminate this agreement and permanently shut off the water from the private fire or sprinkler service, or may impose a fine of not over $100.00. And in case water is found to be running in the fire service, except when being used for extinguishing fires, the service will be shut off and remain off until proper repairs or alterations are made.

Private fire or sprinkler services, including valves, meters, etc., for controlling them, shall be put in at the expense of the property owner, and unler the supervision of the Elmira Water, Light and Railroad Company, who shall be supplied with complete maps and plans of the system.

And it is expressly understood and agreed that the said Company shall not be held to guarantee the sufficiency of its water suply for fire protection in said building; and that said Company shall not be liable for the failure of water through said private fire or sprinkler service, whether occasioned by the scarcity of water in its mains, lack of pressure from any cause, or the breaking of a valve, main or connection, or the shutting off of water for repairs, new connections or for any other cause.

.....

.....

SPECIAL FIRE PROTECTION SERVICES.

By Albert H. Wehr.

The prohibition of the Fire Underwriters' Association against ordinary water meters on private fire protection services, and the excessive cost of the recently devised fire service meters which neither our Company nor our consumers, care to pay, has caused us to devise a set of Rules and Regulations covering special services of this character, which we have found to be satisfactory to us and acceptable to our consumers.

We require every applicant for special fire protection service to enter into an agreement with us as per the form following, and also to furnish us with a bond, with some responsible and reliable bonding company as surety, a copy of the form of this bond being also appended. The rules and regulations embodied in the form of the agreement are modeled largely upon those of the Baltimore City Water Department, with such modifications and additions as are deemed reasonable and proper in the case of a private water works.

THIS AGREEMENT, made this.....(1)..... day of .....(2)....., in the year nineteen hundred and .....(3)..... between .....(4)..... (hereinafter called the "Owner") party of the first part, and THE BALTIMORE COUNTY WATER AND ELECTRIC COMPANY OF BALTIMORE COUNTY, (hereinafter called the "Company") party of the second part, WITNESSETH:

WHEREAS, the Owner is about to install, in.....(5) ....(6)..... building, situate .....(7).....

.....

a Fire Protection .....(8)..... System, and is desirous

that the Company furnish the water supply and service pipe for said system from its mains;

AND WHEREAS, The Company is willing to furnish the necessary water supply and connection therefor, to said system, upon the terms and conditions set forth in the following:

RULES GOVERNING SPECIAL WATER SUPPLIES FOR FIRE PROTECTION.

INSTALLATION OF SERVICE AND CHARGES:

All fire services will be installed by the Company, which will ascertain the best location for same, and lay the pipe from the street main to a point just inside the wall of the building, or within the building line of open yards, where buildings are set back from the building line. The owner will be charged with the exact cost of labor and materials used in the work of installing the service, with an addition of ten per cent. to cover the cost of superintendence and inspection. Payments for installing the service shall be made as follows: Simultaneously with the execution of the agreement for the Fire Protection Service, by the owner, such owner shall pay in advance, to the Company, an amount, which shall be credited against the total cost of installing the service as above set out, based upon the estimated length of the fire service pipe to be installed by the Company, and upon the size of such pipe, at the following rates:

For 4″ service pipe, 40c per lineal foot,
For 6″ service pipe, 60c per lineal foot,
For 8″ service pipe, 90c per lineal foot,
For 10″ service pipe, $1.25 per lineal foot.

and immediately upon the completion of the work of installing said service pipe and the rendition of the bill therefor, the balance of the cost to be charged as above shall be due and payable.

All repairs to the service pipe between the street main and the building or building line, as the case may be, shall be done by the Company at the expense of the Owner.

The annual charges for this service, payable in

advance, as of January 1st, and every year, shall be as follows.

For 4″ service pipe	$ 50.00
For 6″ service pipe	50.00
For 8″ service pipe	100.00
For 10″ service pipe	150.00

SIZE OF SERVICE PIPE.

In all cases the Company shall decide the size of the service pipe required, which shall be determined by the size of the street main, the available pressure on the main, and the nature and capacity of the fire protection equipment within the building. In all cases where underwriters' pumps are to be installed, a suction pipe of sufficient internal area to deliver a quantity of water equal to the full rated capacity of the pipe will be allowed, and no enlargement of said suction pipe inside the premises will be permitted. If, however, this service pipe is run to a surge tank placed in close proximity to the pump, the full size of suction which the pump calls for may be run from the pump to the tank.

NUMBER OF SERVICES:

One service only will be allowed to any one building or premises, unless in the opinion of the Company more than one is absolutely necessary for the proper protection of the premises. All fire protection equipment connected to the Company's service shall be confined within the building or on the premises named in the application, and where two or more connections are made for one building or premises, they shall be kept separated, unless special permission is obtained from the Company to connect the same in a manner to be approved by it.

USE OF FIRE SERVICES.

No water shall be drawn from the fire service pipes for any purpose whatever, except for the extinguishment of fire, and no connection shall be made between the fire service pipe system and the regular water supply to the premises, and the valves on hose outlets, drain cocks, etc., placed on the pipe system shall

be of a style that can be sealed by the Company, and when any such valve or cock is opened, the owner or occupant of the premises shall notify the Company at once, so that the same can be resealed. This paragraph is not to be construed as prohibiting a reasonable use of water for draining of a system to prevent freezing, or other reasonable use in connection with proper fire protection, but does not permit of the use of water through the system for fire drills, except with the consent of the Company first had and obtained by the owner in every instance, when such drill is to be had. Whenever a fire service system is to be tested under the regulations of the fire insurance underwriters, the owner must notify the Company of such proposed test, naming the day and hour when the same is intended to be made, so that, if desired, the Company may have an inspector present during the test.

CONTAMINATION OF WATER SUPPLY.

Any fire protection system supplied with water from the Company's service shall be supplied exclusively with such water, and no connection will be allowed with any other system drawing its supply from any other source whereby the Company's water supply may be contaminated by the failure to close valves, or leaking check valves, etc., and no auxiliary or secondary suction pipe to any underwriter's pump taking water from the harbor, streams, or other source whatever will be permitted. Any fire protection system using water from the harbor, streams or other source than the Company's service, shall be kept separate from any such system supplied from the Company's service.

INSPECTIONS.

All fire services shall be subject to inspection by the Company from time to time, and the owner or tenant shall give the inspectors all reasonable facilities for making the inspections, and any information concerning the same that the inspector or the Company may require. Care will always be taken that inspections will be made with as little inconvenience to the owner or occupant as possible.

PENALTIES.

In any case when the owner or occupant of any premises are found to be using water from a fire service for other purposes than fire protection, or fail to comply with any of the aforegoing Rules not hereafter specifically excepted, the water shall be shut off from the same at once, and the owner shall thereupon immediately be and become liable to the Company for the sum of Five Hundred Dollars ($500.00), as compensation to the Company for any and all damage sustained by it for such wrongful use of its water supply, or for failure to comply with such Rules. In such event the fire service shall be reopened only after such sum of five hundred dollars shall have been paid, and the cause of complaint entirely removed. A second violation of this rule will again make the owner immediately liable to the Company for the second sum of five hundred dollars ($500.00), as in the event of a first violation, and further will be sufficient cause for cutting the service off at the main, and refusing to reconnect the same while the offender occupies the premises.

Failure to pay the balance of the cost of installing the fire service, or any subsequent repairs thereto, or the annual charge for the maintenance of the service, as hereinbefore mentioned, within thirty (30) days after the rendition of the bill therefor, will be sufficient cause for turning off the water from the supply without further notice.

GUARANTEES.

The Company in no manner guarantees to furnish a proper quantity of water through the fire protection service for fire protection, nor does it undertake to guarantee anything relative to any service, but it will make every effort to maintain the efficiency of its service under all conditions. The Company will not be responsible in any manner for failure of its water supply during a fire, or at any other time.

DISCONTINUANCE OF SERVICE.

Any fire service may be discontinued by either

the owner or the Company, at any time, upon thirty (30) days' notice, in writing, sent to the other party to its last known address, through the regular mails or otherwise.

AGREEMENT AND BOND.

A properly drawn agreement covering any fire protection service, embodying all of the above Rules, which shall be a part of said agreement, shall be prepared and executed by both the owner and the Company, and in addition to this agreement the owner shall file with the Company a satisfactory bond, in the penalty of One Thousand Dollars ($1,000.00), conditioned upon the faithful performance of said agreement, with all its conditions as above set forth, and shall continue said bond in force during the continuace of said agreement..

AND WHEREAS, the Owner has applied for an.....(9).....inch fire service connection, to the installation of which size or service the Company has assented, but in no respect has applied for, or been granted, any special connections, uses or privileges relative to said fire service, to which special connections, uses or privileges reference is made in the aforegoing "Rules and Regulations", except as specifically set forth as follows:.....(10).....

NOW, THEREFORE, THIS AGREEMENT WITNESSETH, That for and in consideration of the premises, and of the payment annually of the sum of.....(11)..... Dollars, to be made by the Owner to the Company, as is provided in the "Rules and Regulations", aforesaid, the said Company, upon its part doth hereby covenant and agree to install, at the earliest date possible, and to thereafter maintain, the fire service connection aforesaid, upon the terms and conditions set forth in the aforegoing "Rules and Regulations".

AND the Owner, upon .....(12).....part, doth hereby covenant and agree to make the payments aforesaid, as well as all other payments mentioned to be made in the "Rules and Regulations" aforesaid, as and when the same are, by said "Rules and Regulations" required to be made, and doth further covenant and agree to comply with and be bound by

all the terms, conditions and stipulations set forth in said "Rules and Regulations", and in this Agreement.

..... (13) .....

AS WITNESS the name of the party of the first part, hereunto subscribed by ..... (14) ..... and the name of the party of the second part, hereunto subscribed by its..... President, with its corporate seal affixed, duly attested by its Secretary.

ATTEST:

.....

.....

THE BALTIMORE COUNTY WATER AND ELECTRIC COMPANY OF BALTIMORE COUNTY,

By.....
President.

Attest:

.....
Secretary..

Note:—Fill in blanks to properly meet conditions, as follows:

(1) Date.
(2) Month.
(3) Year.
(4) Full and proper name of applicant.
(5) His, their or its, as the case may be.
(6) Description of building, as "Factory", etc.
(7) Accurate description of location of building.
(8) Style of system, whether "Sprinkler" or "Standpipe".
(9) Size of Service pipe to be installed.
(10) Set forth fully any and all special connections, uses or privileges, if any, which have been allowed, contrary to the Rules and Regulations.

(11) The amount of the annual charge, as per size of service.

(12) His, their or its.

(13) Here insert any other agreements relative to the service or the ownership of the service pipe, etc., which should properly be included in this agreement.

(14) If applicant is an individual, strike out "hereunto subscribed by"; if a partnership, insert name of partner signing; if a corporation, insert "its President, with its corporate seal affixed, duly attested by its secretary".

(FORM OF BOND.)

KNOW ALL MEN BY THESE PRESENTS, That .....(name of applicant).....(hereinafter called the Principal), and the.....(name of Surety)..... Company, a corporation created and existing under the laws of the State of....., and whose principal office is located in.....City, State of ....., (hereinafter called the Surety), are held and firmly bound unto THE BALTIMORE COUNTY WATER AND ELECTRIC COMPANY OF BALTIMORE COUNTY, (hereinafter called the Obligee), in the full and just sum of ONE THOUSAND DOLLARS (1,000.) lawful money of the United States, to be paid to the said Obligee, for which payment, well and truly to be made, the said Principal binds .....self, ...(personal representatives and assigns, if individual of firm, and successors and assigns, if a corporation)....., and the said Surety binds itself, its successors and assigns, jointly and severally, firmly by these presents.

SIGNED AND SEALED this.....day of....., A. D.

THE CONDITION OF THIS OBLIGATION IS SUCH, that whereas the said Principal has executed and entered into a certain agreement with the said Obligee, dated the ..... day of ....., 190....., for Special Water Supply for Fire Protection, in said agreement described, a copy of which agreement is hereto annexed.

NOW, if the said Principal shall well and truly per-

form and observe said agreement and fulfil and perform all and every the covenants and conditions mentioned in said agreement, on.....part to be fulfilled and performed; and shall keep the said Obligee harmless and indemnified from and against all demands, judgments, claims, liens, costs and fees of every description incurred in suits or otherwise, then this obligation shall be void, otherwise the same shall remain in full force and virtue.

PROVIDED, HOWEVER, that in the event of default by the Principal in the fulfilment of any of the covenants and conditions of the said agreement, the Surety shall be promptly notified thereof.

AND PROVIDED, FURTHER, that the Surety may cancel its obligation under the terms of this bond, by giving the Principal and the Obligee thirty (30) days' written notice of its intention and desire so to do, and no liability shall attach to the Surety for any acts or omissions occurring after the expiration of said thirty days.

IN TESTIMONY WHEREOF, the said Principal has caused these presents to be signed and sealed (.....with its corporate seal duly attested by its duly authorized officers) .....or.....(by the several members of said firm)......, and the said Surety has caused these presents to be sealed with its corporate seal, duly attached by the signature of its.....President and its .....Secretary, the day and year first above written.

.....

.....

THE.....Company,

by.....

President.

Attest:

.....

Secretary

JOINT DISCUSSION

On the last four papers.

PREST. MAURY: The Chair would like to say a few words in discussion of this matter. I notice that the writer realizes the undesirability of anything that will cause a stoppage of any sort, or prevent a perfectly free flow at full capacity through the pipes of the fire protection service. At the various conventions of this Association, I have several times brought up the point in that connection on which I have been laboring with friends who are engaged as experts on fire protection matters for the Insurance companies, I have been able to convert some of them and hope that the conversion of others may follow. The practice which I wish once more to condemn, is that of using for fire protection service hydrants with nozzle gates. Right there you have the worst possible obstruction that you can get. Nobody knows whether that gate is open or shut. The firemen do not know. They may have been drilled and instructed in it, but they forget when they come to the fire. The valve stem is necessarily small; the key with which it is operated is generally a combination key with a pretty long leverage, and you can twist off a ½ inch or ⅝ inch brass stem with a very short leverage. I have repeatedly seen those valve stems twisted off, with the result that no stream could be drawn from that nozzle. A long series of mishaps with these gates, in my own city resulted in bringing the Fire Department to the Water Works office for instruction in the use of hydrants. Every fireman on the force was given a drill in the use of hydrants, at the cost of the Water Department. At a large hotel fire, which occurred immediately afterwards there was a 3-nozzle gate hydrant on the corner and a 6-nozzle gate hydrant in the middle of the block, 115 pressure. The firemen, notwithstanding their recent drill and instruction, got one stream off the 3-nozzle hydrant and broke the other two gates; and got one stream off the 6-nozzle hydrant and broke the other five gates. That thing has happened repeatedly, though not always in so aggravated a manner; so I feel I am justified in trying to instill a little of what I might call practical common sense into this use, or misuse, of the hydrant.

Everything that you put in the way of obstruction to the stream is a disadvantage. From the very nature of the case that additional gate upon the nozzle is bound to be in very many instances a disadvantage and an obstruction. It is to be hoped that those who are interested in fire protection may ultimately learn the advisability of having more hydrants, if they want more streams and that the hydrants shall have main gates which are small and easy to open, and no additional nozzle gate.

One other point which is suggested by Mr. Hardy's paper is this: He alludes to the fact that the first function, the prime function of the sprinkler system is to give just at the point at which it is needed—I do not know that he expressed it just this way, but I think this was his idea—water at that point, and no more than that water; and he refers to the economy of the sprinkler system resulting from that feature of its design. I fully agree with him that a sprinkler system should be treated as a "first aid to the injured"; but I want to go further and say, that if a sprinkler system does not accomplish its purpose and stop the fire promptly, then it becomes a menace, as ordinarily designed and equipped, because the fire insurance practice seems rather to be to put in a supply to the sprinkler system which shall be large enough to take care of all the water that all the sprinklers could give if they all went off at once. If the sprinklers do not check the fire with water from a 2-inch or 3-inch main, the sprinkler system is not only useless thereafter, but it becomes a positive menace, because there is a pipe leading into the building in which the fire has got beyond control, which is so large as to seriously handicap the Fire Department in all its efforts to check further progress of the conflagration in that neighborhood. New Englanders, who are forerunners in progressive work, have recognized this point; and in some of the New England cities objecton has been made to anything larger than a four-inch main for private fire service. I think the members of the American Water Works Association might well consider this feature of fire protection.

Mr. Collins: I regret that I didn't hear the whole of

Mr. Hardy's paper. I think a paper of such vast importance as that ought to be one of the very first papers read to the convention. We all know there is considerable feeling between manufacturers and Water Works people in regard to the quantity of water that shall be used at a fire, and considered as free fire protection supply. I do not think any Department in the United States has any objection as to the water that is used in the extinguishing of fires; but a case comes to my mind of a corporation, whose name I will not mention here but will give you privately, so that you may know that what I am telling is absolutely a fact. As Superintendent of the Water Department there was one portion of our city from which I received a considerable number of complaints of rusty water Saturday afternoon or Sunday. I called up this large corporation in that vicinity and asked them if they were using the water. They told me they were not. The gentleman whom I asked is a fine fellow, and I do not think he intended to deceive me in regard to the quantity of water used. I happened to be getting ready to go to church one Sunday morning when I was called up by a complaint of rusty water. I immediately called up the Superintendent of this corporation, and asked him if they had had a breakage. He said "Yes, a 14 inch pipe had broken." I asked him how long it had been running. He said about half an hour. So that that corporation does not give that Water Department one cent for the use of the water. They have an artesian well, and they have may know that what I am telling is absolutely a fact. As eral different times I called them up, and I found that they had been using the water continually. I asked a member of the Fire Department if he thought that was fair to the Water Department? It is just such things as that that tend to make everybody suspicious of corporations. Not only that, but I will say that they had a hydrant put in for no other purpose except fire protection, and they are using city water from it. The other day I caught them shutting off a main, a 16 inch main, and I went in and asked them what was the matter. I found a 6 inch hydrant going full blast at 75 pounds pressure.

In my own opinion, if something could be established between the Underwriters and Water Boards that would give us a fair return and no more, it should be done. Of course we all realized it reduces their insurance. If you attempt to curtail a mill in the use of water, nine-tenths of the community will be against you. They will tell you water does not cost anything. If anything can be done in co-operation with the Underwriters and members of Water Boards, I think it would be a great blessing to all concerned. I hope that something will be done.

MR. WATSON: I had a little experience with one of our consumers that may interest you. Our water works plant is located at Catasauqua, Pennsylvania, supplying nine small towns in two counties. One of these towns has quite a large silk-mill. The superintendent of this factory called upon me and stated he would like to have a 10-inch connection from our street main to supply a sprinkling system which his Company proposed to install. From the fact that our main upon the street at his silk-mill was only 10 inches in size, it almost took my breath away to learn that the Fire Insurance Underwriters should demand a 10-inch supply main or tap. I said, "Do you really mean a 10-inch connection?" and he said, "Yes, that is what the insurance people say we must have. We have a silk-mill here and we want to protect ourselves and we want to protect the town also. If the silk-mill burns down, hundreds of people will be thrown out of employment. Further, we think you should give us this connection without charge."

I said, "You do not want very much, and I cannot see how I can give you what you ask for. We will do all we can for you, but we cannot put a 10-inch connection in at your works. That, if opened, will be a detriment to the other part of the town."

He had a 3-inch connection supplying his boilers by meter measure. I did not know exactly what to do, and after interviewing some of my friends in the water business, we decided that a 6-inch connection would be large enough; that is as large as we could allow on our system at this point. I then informed the silk-mill people that we would not

give a 10-inch connection, but we would give them a 6-inch connection. But in the first place, they must sign a contract agreeing to pay us $80. net, annually, in advance. They finally agreed to that, but, as I understand it, the insurance people told them it would not do, that they must have at least an 8-inch connection.

One of the main points which I want to bring out is this,—that after we had finally agreed upon a 6-inch connection, the revenue from meter measurement by the 3-inch service at once commenced to grow less each month. They informed our inspector, however, that they had a connection with the creek. It was not long before, owing to the very bad condition of the water in the creek, a typhoid epidemic broke out in this mill, and they were notified by the Board of Health that if they did not discontinue the use of the creek water, and use the city supply, that the mill would be ordered closed.

Consumption by meter then increased somewhat as our inspector was instructed to take meter readings twice or three times each week. I am, however, since hearing the several discussions on this paper, convinced that water is being taken from the 6-inch fire service line and will, as soon as I returned, place a small by-pass meter around the 6-inch valve controlling the service at the street curb line, and from time to time order the valve closed by the inspector that any consumption may be detected.

The other point which I think is important to the water works men is that whenever a Sprinkling System or fire line is requested by the consumer, there should be an understanding between the water works men and the insurance people that they supply the Superintendent of the Water Company with a full detailed drawing or plan of the pipes and connections leading from the fire service line supply.

It is not difficult for a Water Works Superintendent to trace a 4-inch or 6-inch line supplying two fire hydrants or more on the property of a manufacturer, but it is almost impossible to trace the small and large supply pipes throughout a silk-mill containing the sprinkling system.

I therefore request that this point of supplying the

water works plant with plans of all pipes connected with the fire system be further considered by our Association, and if thought advisable, some action taken on the subject.

MR. CARLIN: In our city (Sioux City, Ia.) we enter into a contract with large consumers when we place a 6-inch connection in their buildings. We compel them to furnish us a plat of the pipe lines in place on their grounds. But that doesn't stop the leaks. As President Maury said a little while ago, we still find that there are leaks there notwithstanding the contract. We also reserve the right to place detector or other meters on such lines. That is in our contract. Our supply at Sioux City is limited. We find that on Sundays the draught on the water is very heavy, more so than on any other day, which ought not to be; that is, in summer time. In tracing up this matter we found where the leak was, and we will be compelled to place meters on these 6-inch lines notwithstanding the insurance companies' objections.

MR. CAULFIELD: St. Paul has had considerable trouble with the demands of the insurance people. One concern there had three 6-inch pipes and did not take any water from us at all. Another had two 6-inch pipes. The Board fixed a charge for this kind of service a year ago, the result of which was that one concern applied for an injunction to prevent us from enforcing the rate, which was granted by the District Court. We appealed to the Supreme Court, and were defeated on the point that we had given credit on the sprinkler system for the amount of water that was used through the meter to the extent only, of course, of the charge for the sprinkling system. The Court decided that we had the right to charge a reasonable sum for the use of these devices, but that this was a special device only used by a favored few who receive large returns on account of having that system.

PREST. MAURY: As I understand it, the decision against you was the result of the existing contractual relations, the decision being in your favor in so far as the right to charge for fire protection was concerned?

MR. CAULFIELD: Yes; on the other hand, the decision was against us as discriminating for use of water through meters. They said we might as well give credit to a water consumer for the amount that he paid for grading the street.

The case was carried to the Supreme Court of the State of Minnesota, which affirmed the opinion of the trial court, granting an injunction against the defendant Water Board from the severance of the connection of water mains with the fire system.

In its decision the Court said, in part:

"Rules of a Water Board giving credit for water con-
"sumed through small pipes supplied with meters upon
"charges for unmetered connections of a building using an
"automatic sprinkling device with water mains, held dis-
"criminatory and void because lacking uniformity in prin-
"ciple and in operation."

"A property owner who has installed such a system
"and connected it at his own expense with the water mains,
"although he may not take away water except in case of fire,
"enjoys a beneficial use of water not common to the public
"in general. The Water Board is entitled to make a reason-
"able and impartial charge for the pecuniarily valuable and
"special privilege conferred.

"The Water Board will not be permitted to enforce
"illegal rates by severing the connection of such a sprink-
"ling device. Courts will interfere by injunction or other-
"wise to protect the public and individuals entitled to water
"service against unreasonable charges or discriminations
"made by public utility corporations or bodies."

"The first question on the merits is, whether the rules
"were impartial or discriminatory. 'The Board insists that
" 'the only way in which it can place the unmetered sprink-
" 'lers as nearly as possible upon the same basis as those
" 'using meters in large connections was to give them credit
" 'for water consumed through their small meter service
" 'pipes which they all had. This was the reason for the
" 'adoption of Rule 24. It puts them all on a uniform ba-
" 'sis'. In point of fact, however, a uniform basis did not
"result either in the rule itself or its actual operation. If
"the postoffice undertook, to a limited extent, to deduct the

"postage on one class of matter from the postage on another, "or if a railway company allowed to a limited extent a re- "bate on freight rates to the amount of passenger tickets "bought, there would be a similar and certainly illegal dis- "crimination. A more nearly analogous case of equally "clear illegality would be the permission, to a limited extent, "to deduct from water charges the amount paid for street "paving or sewer construction, where the City operated the "water system directly. The rules here involved enable "persons having a sprinkling assessment and using also "meter service to pay the sprinkling charge by the pur- "chase of meter service. There is no more reason why "they should be entitled to satisfy this public charge by buy- "ing water than by buying anything else. The discrimina- "tion resulting in fact is apparent from the difference in "charges shown by the record to have been made to in- "dividuals of the same class for the identically same service."

"The second question on the merits concerns the right of "the City to make any charge whatever for this sprink- "ling connection. Among the pertinent considerations press- "ed upon our attention are the following: The City is "put to no expense generally by virtue of the sprinkling "connections or specifically because of any necessity to "maintain a given hydrostatic pressure. The mechanical "contrivance is such that sufficient water pressure is main- "tained within the building to resist the pressure in the pipes. "Further: While the City has a right to make a charge for "water consumed for ordinary purposes, it has no right to "charge for water supplied for protection from fire; as a "matter of fact no charge is made or could be made for "water used by the Fire Department in extinguishing a "fire, although a single individual only would be benefit- "ted thereby. Individuals should not be required to pay "water rates as a penalty for increasing the sufficiency of "the Fire Department at their own expense by providing "extraordinary and sufficient means of extinguishing fires "immediately when they start.

"We are of opinion that the argument does not justi- "fy the conclusion. So long as water supplied for protec- "tion against fire is a purely public service, under the control "and management of municipal authorities generally, and "under the Fire Department specifically, no direct charge

"to individuals is proper. When, however, a sprinkling "connection is made with private premises, the situation "is materially different. These premises and the primary "causes of catastrophe to the building and of the conse- "quent possible use of disastrous quantities of water, are "primarily under the control, not of the public, but of the "owner. A peculiar personal service is provided for his "benefit, which is not enjoyed in common by the community "in general, but is available only to a limited class of indi- "viduals."

Our Board has finally changed its rule, and is charging every sprinkler consumer a rate without giving any credit. They are also refusing to give any service larger than a 4-inch pipe. We give 2-inch and 3-inch, and in some cases 4-inch pipes. Our rate has been reduced since this decision, but our sprinkler consumers are not satisfied.

One of the matters that I should like to have discussed is this question of fixing rates, I should, also, like to have a table prepared, if possible, by the different Water Works people, showing their charges for sprinkler service, size of pipe and number of pipes.

MR. MONTEVERDE: Do you know if the Insurance people would have any objections to using a pitometer on fire service lines?

PREST. MAURY: I should think they certainly would not.

MR. NOURSE: I have found the Fire protection people very easily satisfied in matters of this kind; in fact, I believe that my attendance at the convention at St. Louis has been worth more money to the City of Chicago along that line than perhaps any other thing that I have learned. You may remember that in St. Louis we had this discussion up with the Fire folks. I have forgotten the names of the gentlemen, but I recognized while they were talking that they drew a line between the cities that had high pressure and the cities that had no pressure; that is to say, too low to be depended upon for fire protection. In Chicago, we have no pressure that they care anything for, the pressure at fires being furnished by steamers. In answer to a ques-

tion that I put there, one of the gentlemen said very politely, that they did not care anything about conditions in Chicago. I thanked him for it, and when I got home I asked my superior officer to go to the Council with me and ask for the passage of an ordinance requiring all fire lines to be metered; and we added to that ordinance, that no by-pass under any circumstances should be put in; further, that any by-pass in existence should be taken out. We meter everything in connection with the fire system, whether it is to a sprinkler line or whether it is to a large service to be opened only in case of fire, and if there is any water used through that meter at any time, other than when a fire takes place, they pay for it at the tariff rates. If there is any water used at the time a fire takes place, we average up to the time of the fire, the Fire Department's statement being taken as to the duration of the fire, read the meter immediately after, and subtract the amount that is consumed while the fire is going on, and decrease it from the books. That seems fair to everybody. When we commenced to give notice that we were going to remove by-passes from the Stock-Yards district, the patrons in the district did everything that they could, as they usually do in such cases to delay the removal of the by-passes. We did not go into court, but we went to our corporation counsel's office, and the Finance Committee. Recently I got a letter from the Finance Committee that the corporation counsel had decided that our action in regard to the removal of by-passes is valid and substantial law. We are going to take them all out. We put two meters in now, one that they use water through for their business purposes, and the other for fire line. I think I have got more satisfaction from that talk with the Fire Protection people at the St. Louis convention than anything else I did there.

MR. MAURY: I have had occasion during the last year to look into a good many of the requirements of Fire Protection Associations, these requirements, being always accompanied by a notification of an immediate and definite increase in rates, and an indefinite promise that at some

future time—but not before all of the requirements have been complied with in each particular department—the rates would be lowered. The belief has gained ground in a good many places, I have found, that as regards these requirements in particular cities where the rates have been raised by shoving up the basis rate, there has sometimes been less consideration of the merits of the case in those particular cities, than of the fact that it was necessary very promptly to recoup the unusual losses at Baltimore, San Francisco, Toronto and elsewhere; and I have been compelled to the conclusion that there was some ground for that belief.

In view of the magnitude of their recent losses, it is not, perhaps, unnatural for the Insurance Companies to try to raise their rates as much as possible, and as soon as possible; and I do not doubt that the financial exigencies of the situation have been responsible for much of the injustice referred to.

I do not think that metering fire protection lines—large pipes metered with large meters—affords the Water Department protection, because through a six-inch meter, for example, especially if it shall have remained long in disuse, it is entirely possible for a man to draw for his ordinary consumption, especially if he draw it into tanks at relatively small rates, a very large aggregate amount of water, without the meter indicating it. And when you have put on that meter, and rely upon it as your spy and detector, you have practically forfeited every other means of making that man comply with his contract not to draw water for other than fire uses.

No matter how you guard this proposition, to put in these large connections for special fire service is, in fact, like giving a blank check on your water supply. There are several ingenious devices which will, if there be no dishonest intentions on the part of the owner of the plant, bring to notice any accidental misuse of water. The accidental ones are always easy to settle. There is comparatively little trouble, as a rule, in getting at them. But if a dishonest intention be present on the part of the manager of the specially protected industrial establishment, he can,

and often will, find means to beat the best mechanical devices that can be put on pipes to stop it.

MR. NOURSE: When you come to the question of a fire or conflagration such as you have presented, the question of meter or no meter cuts no figure at all; the business has gone beyond the control of any meter, key, valve, gate or anything else. The question of the waste of water is mainly from small losses going on all over a large plant, such as we have in Chicago particularly.

MR. HEWITT: I have had a similar experience to these gentlemen; but in every case where we put on a fire supply, I found them doing what they have been doing in other cases. We make no charge for fire connection, which consequently makes it all the worse for us. In one case I found out by a by-pass meter that water was going through. As soon as I could I had my Chairman come and see it. The water was going through at the rate of 27 gallons a minute. When I got the Chairman there, lo and behold you, the water was flowing into our main at the rate of 2 feet a minute, that is they were pumping into the fire main to defeat the test I was making. In my opinion nothing else but a detector meter placed there on watch day and night, will accomplish your purpose. While that leak was detected two years ago, I found it varied at different times, ranging from 9 gallons a minute to 27 gallons, and it is going yet.

MR. REIMER: I do not know why East Orange should be different from other places, but we have met with no opposition. In the case of a fire service, a valve should be placed at some outside point and be sealed with a lead stamp, or official seal. That seal is capable of being broken by a slight twist of the wheel governing the valve that supplies the sprinkler heads. We do not leave the water on the fire line inside of the building, but instructions are given by the factory to the employes that in case of any fire they must immediately open that particular valve.

MR. FRENCH: The New Jersey people are apparently a little more honest than they seem to be in some other parts of the Country. These papers and discussions have

been very interesting to me and I think it only fair to add something from my own experience.

We have been dealing with this question for several years and we have many such connections to manufacturing and industrial plants. We are satisfied to deal with the subject of water supply to "Private Fire Service" in two ways:

1st. By furnishing a connection such as is required and metering it, the meter to be provided with a by-pass the full size of the pipe and the by-pass gate to be closed and sealed and an agreement in writing to the effect that it shall not be opened except in case of fire. This plan provides for an immediate supply and it is the consumer's privilege to open the by-pass full in case of fire.

2nd. If there be any objection to the first plan, we will furnish a fire line without a meter and charge for such service 50% of the regular minimum meter rate, dependent upon the size of the pipe, and with an agreement in writing that no water shall be used from this line except in case of fire.

With this latter plan the consumer must run a second line for his supply for manufacturing and general purposes.

I think there is another side to the whole question of furnishing water for fire protection that has not been brought out in this discussion.

I believe we all recognize the fact that the amount of water used at fires is comparatively trifling. It is a fairly big fire that uses one million gallons of water. We are a private corporation and not in business for our health precisely, but trying to give good service, and we expect something for it. If we have a consumer whose water bills amount to, say $500. per month, I confess that I am very ready in case that industry gets on fire to give them everything we can to control it, and if we succeed in doing that, it keeps the manufacturing industry in operation, which is usually a public good, and they go on consuming water uninterruptedly instead of being shut down for six months, or perhaps longer, making repairs.

I believe it is a good business for a water company to protect such an industry to its fullest extent from a finan-

cial standpoint. I do not mean to say, however, that we ought to do this at the expense of everybody else, but if the pipe system is adequate, such usage is a matter of a few hours only, at the most, with perhaps a slight loss in pressure, and if the system is inadequate the Water Company should not allow a connection so large that they would be seriously embarrassed by its full opening.

I think there is a danger in connection with a metered fire service of meters becoming clogged, due to the increased velocity of water (in case of fire) carrying along with it something in the pipe system that would not move under the normal rate of service.

THE SANITARY PROTECTION OF SURFACE WATER SUPPLIES.

By George A. Soper.

Considering the extent to which surface water supplies can be protected against pollution, and the terrible results which have followed neglect in this direction, it is remarkable that water works authorities have been so indifferent to work of this kind. It is true that efforts of one sort or another are often made to prevent pollution, but the opinion gained by a careful consideration of what is being done throughout the country is that surface water supplies are generally not protected in anything like the thorough and systematic manner desirable.

There is no use hiding the facts. Many water supplies are continually polluted through lack of care to keep them clean. Nearly every typhoid epidemic shows how avoidable are these insanitary conditions. Let us glance for a moment at some of the object lessons of this kind which have been given in recent years.

Turning to the records of some of the greatest epidemics caused by water supplies, as given in the last number of the Proceedings of this Association, we may pick out those which, in the light of present knowledge, we may say would be wholly preventable to-day.

Beginning with Caterham, where a filthy water works employee was allowed to pollute the water, and ending with Butler, where water from the polluted drainage area was passed not through but by the customary filters through the city, we find in twenty-four years, ten severe epidemics with 14,399 cases and 1,142 deaths in an aggregate population of 607,000.

And these epidemics by no means represent all of the outbreaks of typhoid fever which have been caused by contaminated water. They are cited only as examples. Nor do they take account of that vastly greater amount of sick-

ness and death due to carelessly polluted water which goes steadily on year by year without attracting particular attention. If water supplies were protected in the systematic manner proposed in this paper, a large part of this misery could be prevented.

PROTECTIVE AND CORRECTIVE MEASURES COMPARED.

At one time something like an excuse existed when a city was supplied with contaminated water, for sanitary experts believed that running streams purified themselves. In those days it was thought that there was no harm in using rivers and lakes both as sources of water supply and places for the discharge of sewage.

Later, it was found that this was a mistake and filtration was hailed as the necessary and sufficient antidote for the poison of polluted water. But prevention is better than cure and to-day it is suggested that a proper way of dealing with polluted water supplies is often to take steps to prevent the contamination.

If any confusion seems to exist between these two principles of protection and correction, it is because their fields of usefulness are not always clearly understood. No real antagonism can exist concerning the ways in which clean and safe water can be obtained. Filters have their functions, as have methods of clarification, disinfection and conservancy. Every measure probably has its own merits and its own restrictions. All of course have a common object which is to insure for the consumers safe and attractive drinking water.

Filtration and other methods of purifying water occupy a distinct field in that they are capable of cleaning water which has become dirty and infested with disease germs. All other measures belong strictly to the field of prevention. In some cases preventive work is capable of postponing, if not making unnecessary, the application of a cure; in others it is a necessary accompaniment of it. Preventive measures will be desirable as long and wherever pure water is valued. No matter how effectively it appears possible to remove the danger and the dirt, it will always be desirable to keep out as much of it as possible.

SPECIAL NECESSITY FOR AVOIDING ACCIDENTAL CONTAMINATIONS.

Too much reliance should not be placed upon the efficacy of sewage purification in protecting a water supply, for while plants can be built to handle sewage and mill wastes in any quantity, and may be turned to excellent account in guarding water supplies against one of the most prevalent forms of contamination, it cannot be assumed that anything like the whole work of protecting water supplies lies in excluding the sewage of cities and villages. Even if used to the theoretical limit, sewage disposal plants are not capable of doing all that is necessary. They can keep out the major part of such polluting matters as sewage, or, as we may say, deliberate contamination, but even in this direction they are less effective than is popularly supposed. They are, of course, quite incapable of taking care of what may be termed accidental contamination.

Now, the history of epidemics shows that the accidental contamination of water supplies is especially to be feared. It was this kind of pollution which produced all of the typhoid outbreaks to which we have just referred.

Accidental contamination is most likely to occur at wholly unprotected places, such, for example, as farmhouses, labor camps and railway lines. Too often the source of pollution which leads to an epidemic is unknown and unsuspected by the water works authorities, although in some instances it has existed for a long time. As a rule the important sources of pollution exist or are imminent, quite long enough to be detected by a rational system of conservancy before any serious harm is done to the water supply. It is in fact often surprising to see how openly water supplies are polluted. There is rarely anything hidden or malicious about it. The contamination occurs as a result of a perfectly natural desire to get rid of something which is offensive.

The supplies over which it is most difficult to exercise

control are those which are obtained from large rivers. In this case the drainage area is extensive and the conditions of pollution numerous, complex and often beyond the jurisdiction of a single sanitary authority.

Supplies which are easiest to control are those which are impounded, of moderate size, and within a single state or county. In other words, other things being equal, the practicability of carrying on a successful scheme of conservancy depends largely upon the ratio of the water needed to the total volume which requires to be protected in order that the supply shall be safe.

MEASURES AVAILABLE FOR SYSTEMATIC PROTECTION.

Systematic protection aims to prevent both continuous and accidental contaminations by controlling the conditions which lead up to them. It seeks to keep out of the water all of the dangerous matters which it is feasible to keep out and in doing so makes use of whatever means law and the ingenuity which water works people can bring to bear upon the subject.

Among the measures available for prosecuting this work are the following:

(1) THE PURCHASE OF LAND.

This is probably the most expensive kind of protection and is generally suitable only for the care of reservoirs, and the territory immediately adjoining them. In some cases, however, it has been thought necessary to buy extensive pieces of property on the drainage area in order to control the sanitary conditions on them. As a practical means of protecting the purity of streams, it has but limited application.

(2) SEWERAGE AND SEWAGE DISPOSAL PLANTS

These to take care especially of the drainage of cities, towns, villages, institutions, factories and private estates.

In most instances not only sewage but sewage purification is necessary, but in others the drainage is carried outside of the water shed.

Works of this character have been constructed in some cases at the expense of the municipalities whose drainage has been cared for, but in others they have had to be built at the cost of the water works which received the benefit. In a few instances the expense has been shared. There is this advantage when the plants are built at the expense of the water works, they can be operated in a competent manner. Excepting where the water works pay the bill, this line of preventive work must be pushed, as a rule, by legal force.

(3) DOMESTIC SANITARY ARRANGEMENTS

Improvements of this kind include well built privies, cesspools, manure pits and other arrangements for the disposal of the refuse of farmhouses, dairies, stables and places for keeping horses, cattle, hogs and other animals. They include the care of the drainage of highways and railways.

The detailed work to be done is various in character and amount. Earth closets, tight cesspools, pits and filter beds are among the measures which are available for handling the drainage of permanent places where defilement might occur. Tanks carried beneath the cars have been suggested for railways. Economy requires that for each danger spot an adequate and permanent remedy should be prescribed.

The cost of the improvements included in this class may often, with a little diplomacy, be shared between the water works authorities and those whose wastes would otherwise pollute the supply, on the theory that both receive distinct benefit from the improved sanitary conditions. This work can be appropriately pushed by personal conferences with the property holders. It requires that the representative of the water works be unusually intelligent and competent to deal with the rural classes.

(4) SANITARY MANAGEMENT OF CONDITIONS SURROUNDING THE SICK.

This sometimes means supervision over the location of cemeteries and hospitals and always the regulation of the methods used in disposing of the infectious excretions from patients suffering from typhoid fever and other enteric diseases on the drainage area.

Work of this kind requires the expenditure of comparatively little money, but calls for the exercise of much vigilance on the part of water works authorities. It requires the co-operation of health boards and the friendly aid of physicians who practice within the water shed. The water works should be kept informed of every case of typhoid known to the physicians on the drainage area, and should see that the wastes from these cases are properly disposed of. All protracted cases of fever, of dysentery and of diarrhea, not diagnosed as a disease well recognized in text books of hygiene or medicine should be suspected of being typhoid. This is an extremely delicate and important kind of work, and is especially worthy of the best attention of the water works management.

(5) RULES CONCERNING SUCH MATTERS AS BOATING, BATHING AND FISHING, SKATING, ICE CUTTING, AND THE WATERING OF CATTLE.

The enforcement of such rules costs but little money when carried on in connection with a general scheme of conservancy and, when legal authority can be obtained for it, presents no serious difficulties not included in carrying out other lines of systematic protection.

Sufficiently complete legal control over the principal places where defilement is likely to occur and a liberal policy of issuing permits to responsible persons who wish to make proper uses of the water are capable of pushing this kind of work to good advantage.

(6) WATER ANALYSES.

Arrangements should be made for the collection and analysis of such samples as will give a constant and reliable guide to the quality of the water. These analyses need not be elaborate, but they must be accurate. They can often be made at comparatively small cost by arrangement with some well equipped college or state board of health laboratory. Some few simple tests can be made by water works people themselves, but, as a rule, these will not be useful as guides to the sanitary quality of the water.

The reports of the analyses should be promptly interpreted and when the results suggest pollution, the cause should immediately be investigated.

(7) INSPECTIONS.

To carry out a comprehensive scheme of sanitary protection, there are needed inspectors enough to visit the drainage area with sufficient frequency to enable a complete and reliable record of the sanitary conditions to be kept at the office of the water works. These men need not be highly skilled in sanitary subjects, but they should be under the direction of some one who has both a theoretical and practical knowledge of the subject.

(8) OFFICE WORK.

This means note books, blank forms, records, maps and blue prints, and the calculations which go with them.

In short, something of the same kind of system is needed to watch and protect the water before it is supplied to the consumers as is already in force in every well kept water works office to control and keep track of its distribution.

The whole work should be planned and executed with as much deliberation and skill as any other water works undertaking. Everything should be done deliberately, thoroughly, impartially and with the object of requiring only such improvements and restrictions as are indispensible and likely to prove permanently satisfactory.

THE POSSIBILITY OF WATERS, IN MAINS UNDER PRESSURE, BECOMING POLLUTED FROM EXTERNAL SOURCES.

By James M. Caird.

At the Convention of the American Water Works Association, held in Boston, Mass., July, 1906, the following question was asked:

Is it possible for surface water to enter a water main through a leaky joint or other opening, when the main is under pressure? Would the principle of endosmose or exosmose apply in such a case?

At that convention remarks were made upon this subject by Mr. John M. Diven, secy., Charleston, S. C., and Mr. M. L. Worrell, secy., Water Company, Selma, Ala.

In Webster's dictionary "OSMOSE" is defined as follows: "The tendency in fluids to mix, or become equally diffused, when in contact. It was first observed between fluids of differing densities, and as taking place through a membrane or an intervening porous structure. The more rapid flow from the thinner to the thicker fluid was then called ENDOSMOSE and the opposite, slower current, EXOSMOSE. Both are, however, results of the same force, OSMOSE may be regarded as a form of molecular attraction, allied to that of adhesion."

I quote from a report which was written by on officer of a State Board of Health.

"It is possible that the main leading from the pumping station to the filtration plant is leaky, and that surface drainage finds its way into the pipe, and this would account for the presence of a larger number of bacteria at the filtration plant than at the pumping station."

This opinion was based upon the results of the bacterial examination of two samples of water, one being taken at each end of a line, which was about 1 1-2 miles in length.

In this case the water was passing through the main

under a pressure of from 10 to 75 lbs. This main is always under a static pressure of from 23 to 120 feet.

The writer has been called upon on several occasions to test the quality of a water before and after passing through mains which were laid under streams, the question being asked "Is the water in the main being polluted from outside sources?" The supposition being that under such conditions, the water in passing through the mains, acts upon the same principle as the "Richards Pump".

I have never been able to detect any difference in the composition of these waters after applying chemical and bacterial tests.

An apparatus equipped for making some of these tests was kindly furnished by Mr. John M. Diven, secy.

This apparatus consisted of an iron tank 12 feet high and 4 feet in diameter, a 3-4 inch pipe being connected with the supply main in the street and passing through the tank, near the bottom. The supply pipe was "tapped" in the interior of the tank, and a 1-2 inch valve put on the opening with a "key" running to the top of the tank, so that the opening of this valve could be easily controlled.

A pressure gauge was also placed upon the supply pipe.

The tank had a 2 inch overflow pipe 4 inches from the top, also a float gauge to indicate the height of the water over the opening of the 1-2 inch valve in the bottom of the tank.

The first test was started when the height of the water in the tank was 5 feet over the 1-2 inch valve (c) which was in the pipe line passing through the tank.

The capacity of the tank was 94 gallons per foot.

The static pressure on the 3-4-inch pipe passing through the tank was 45 lbs.

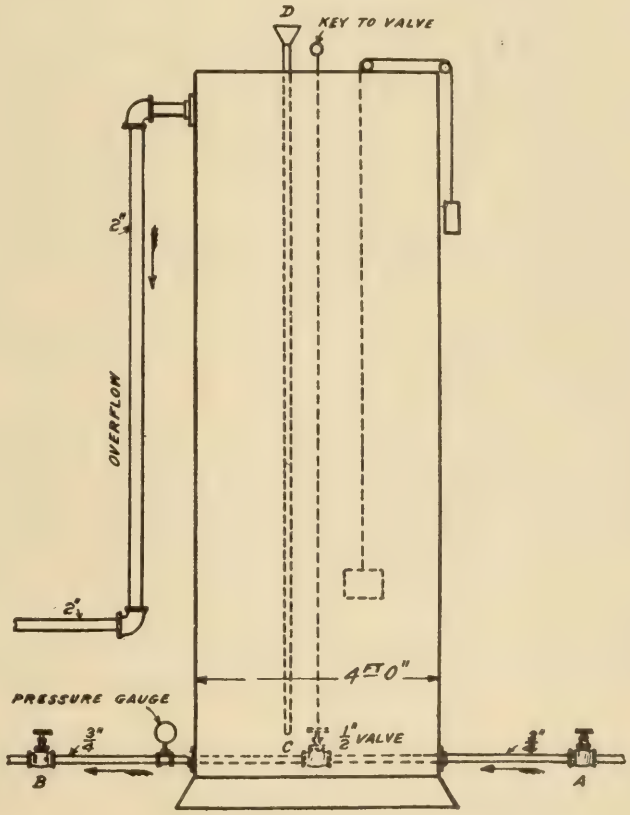
The water in the tank was deeply colored by the addition of a solution of potassium permanganate, more of the solution being added from time to time. The additional permanganate solution was added through a 3-4-inch pipe which discharged in front of valve (c) thereby insuring a thorough mixing with the incoming or out going water.

As previously stated, the pipe was covered with 5 feet

JAMES M. CAIRD

CHEMIST & BACTERIOLOGIST.

TROY, N.Y.



of water; valve "b" was opened to reduce the pressure 5 lbs., afterwards valve "c" was opened reducing the pressure 5 lbs. more; making a total reduction of 10 lbs. The color of the water as it was leaving the pipe at valve "b" was tested at short intervalves, but no pink coloration could be detected. During the first hour the height of the water over valve "c" increased 15 inches ,which was equal to a discharge of 117.5 gallons from valve "c".

In three hours the tank overflowed, at which time the pipe was covered by 10 feet-10 inches, an increase of 5 feet 10 inches in the water cover, or a discharge of 548.4 gallons of water from valve "c".

As the tank was overflowing, additional permanganate solution was added through pipe "d" for the purpose of keeping the water in the tank highly colored.

From time to time valve "c" was opened until it reached its full capacity, at which time by opening it had reduced the pressure 29 lbs; altogether the pressure was reduced a total of 34 lbs.

Up to this time no pink coloration could be detected in the discharge at valve "b".

After this, valve "a" was slowly closed until the height of the solution in the tank produced slightly more pressure than that in the supply main and as was to be expected the discharge from valve "b" immediately became highly colored.

In the second test the water in the tank was 5 feet over valve "c" when a solution of common salt (10 lbs.) was added.

As in the previous test, valve "b" was opened in order to reduce the pressure 5 lbs.; then valve "c" was opened reducing the pressure an additional 5 lbs. making a total reduction of 10 lbs.

Samples of the water at valve "a" and "b" were tested at frequent intervals, but no increase in chlorine could be found.

Two hours and forty minutes after starting this test the tank began to overflow, at this time valve "c" was covered by 10 feet 10 inches of saline water; the increase in cover

being 5 feet 10 inches which was equal to a discharge of 548.4 gallons from valve "c" in this short time.

After the water was overflowing the tank, valve "c" was opened wide which caused a total reduction of 42 lbs. in the pressure.

The static pressure when starting this test was 54 lbs.

At no time during this test could any difference in the chlorine contents of the waters be found.

Twenty-four hours after starting the test, the water overflowing from the tank was "normal" in chlorine.

At the start of the test the pipe was covered 5 feet with water, this being about the average covering of mains that are laid in the northern climates and in shallow streams.

The "leak" was small at the start, and increased as the depth of the cover was raised, throughout the test, conditions were obtained as near ordinary conditions as possible.

Of course this test does not apply to "suction mains", but would hold good for force mains and distribution systems.

DISCUSSION.

MR. HAGUE: Of course we all know that the pressure in a main in such a case is greater on the inside than the outside, and the flow will be out through any aperture; but in this main there might have been times when the pressure was off, although there was some saturation in the soil that might have given an excessive pressure on the outside. The data is hardly sufficient to form an opinion on such a complicated matter.

MR. DIVEN: In the case at Elmira it was impossible for this head to be less than about 26 ft. on the pipe, and the pipe was not covered to more than 5 ft. at any place; so that the soil water could not have been more than 5 ft. above the pipe; while the water in the pipe stood 26 ft. there must have been an excess of pressure. Now how reliable the examinations made by this man, who was an official in the service of the State, were, I do not know. I doubted them at the time; but I have had it in my mind ever since to make some such experiment; and while I was convinced before I saw them made as to what the results would be, still I am more thoroughly convinced now. I do not believe there is any possibility of water leaking into such a pipe through an aperture by any combination of circumstances.

MR. HAGUE: Either there were some conditions that you did not obtain, or else the Commission is mistaken.

MR. DIVEN: This experiment was intended to come as near the actual working conditions as possible.

MR. HAGUE: Was it political contamination or just chemical corruption?

MR. DIVEN: I do not know; that is the question.

AN EFFECTIVE FOLLOW-UP SYSTEM FOR COMPLAINTS.

By Albert H. Wehr.

Our experience with complaints has been, that by far the majority come from "chronic kickers". Formerly, when a complaint was received at our office, instructions were sent out to the proper street foreman to give the same prompt attention. Usually these instructions were followed, and nothing more was heard of the matter, so that it was assumed that the customer had been properly looked after. Occasionally the same complaint would be made several weeks later, and upon investigation, it was found, either that the foreman, in the rush of other work, had overlooked the complaint entirely, or that he had sent one of his men who gave the trouble only scant attention; and sometimes the customer "kicked" again on general principles.

The following method of keeping track of all complaints, until each is finally disposed of, to the satisfaction of the person making the complaint, has accordingly been devised. Upon the receipt of a complaint at our office, whether made in person, by telephone or by letter, the following "Form No. 1" is filled out at once and is addressed to and sent to our Superintendent, or in his absence, to such person who is in charge of our mechanical department.

(FORM NO. 1)

THE BALTIMORE COUNTY WATER AND ELECTRIC CO.

Baltimore.....190.....

Mr. .....

The following complaint has been received:

.....

.....

.....Treasurer.

Baltimore,.....190.....

Treasurer:

I have investigated above complaint and report:

.....

At the same time the complaint is noted on a reply postal card in the following Form No. 2:

(FORM NO. 2. FRONT)

THE BALTIMORE COUNTY WATER & ELECTRIC CO.,

411 E. Baltimore Street,

BALTIMORE, MD

No..... *Baltimore*,.....190.....

We have noted Complaint from you as follows:

.....

Kindly fill out the return postal card, stating whether the matter has been attended to, to your satisfaction.

Your prompt reply wil be appreciated.

Yours very truly,

The Baltimore County Water & Electric Co.,

(BOTH TELEPHONES.) 411 E. BALTIMORE ST.

(FORM NO. 2. REVERSE)

PLEASE TEAR OFF HERE AND RETURN.

No...... *Date*.....190.....

Relative to my recent Complaint, I desire to state:—

.....

Yours truly,

.....

Address: .....

This reply postal is then properly addressed to the person making the complaint, and is filed where it is constantly before our office men.

Upon receipt of Form No. 1, by the Superintendent, he fills in a work order blank, as per Form No. 3:

(FORM NO. 3.)

No..... .....190.....

Mr.....

Please .....

.....

.....

.....

charge to .....

Company acct. .....District.....

(Signed)

.....

This Form No. 3, is bound in books, manilla backs cut flush, of fifty each, and between each of these sheets there is bound a manilla card, perforated at one, end so that it may be easily removed, containing Form No. 4:

(FORM NO. 4.)

(FRONT)

THE BALTIMORE COUNTY WATER AND ELECTRIC CO.

No..... .....190.....

Mr.....

Please.....

.....

.....

charge to .....

.....

Company acct.....District.....

(*Signed*)

.....

Executed)
Cancelled)

.....190.....

(*Signed*) .....

(REVERSE)

TIME

AMOUNT											
@											
HOURS											

ARTICLES	Quantity	@	Amount

By inserting a piece of carbon paper between Forms Nos. 3 and 4, the one writing gives the Superintendent both his office copy and the street foreman's card copy of the instruction to correct the complaint.

Form No. 4 is then sent to the proper street foreman, who, after attending to the matter, dates and signs the card at the bottom, fills in the time and material consumed in correcting the complaint on the reverse side, and sends the card back to the Superintendent. The latter then checks his office copy, thus showing that the foreman's card has been returned; he then notes the fact that the complaint has been attended to on the bottom of Form No. 1, which he then returns to the office, at the same time turning in the foreman's card to the book-keeper, who makes up the charge to the customer affected, if any, and then files the card for future reference.

Upon receipt of Form No. 1 from the Superintendent, the return postal (Form No. 2) is mailed, Form No. 1, is filed, and the matter dropped, except that the reply from the customer or person complaining, is filed, if one is received. Should the customer report that his complaint has not been satisfactorily attended to, then another Form No. 1, is filled out, and with the customer's reply that he is not satisfied, attached, is sent again to the Superintendent, another reply postal (Form No. 2) being filled out at the same time and filed for mailing when the second report is received.

The file of "unattended to" reply postals is looked over at intervals of two or three days, and the Superintendent's attention called to such complaints as have not been promptly corrected and reported back.

This system may appear somewhat cumbersome, but it has proven itself to be effective, because, first, of the fact that our street foremen and their men are desirous of avoiding criticism of their work from the customer after it has been reported that the complaint has been properly looked after, and either the foreman, or his men, therefore, usually consult the customer as to whether or not he is satisfied, before leaving the job; and, second, the customer, being given an opportunity to "kick" a second time, without expense or trouble further than the writing of a few words,

does not hesitate to let us hear from him, if he is not reasonably satisfied with the attention given to his complaint.

We find that comparatively few of the reply postals sent out are returned, but of those returned, practically none make further complaint. It seems, therefore, from our experience, to be a fair inference, that a silent customer is a satisfied customer. In any event, our system has made our street men more careful of their work, and more courteous to our customers, and we have, temporarily, at least, cured some "kickers" of a chronic malady.

LABORATORY EXPERIMENTS IN WATER TREATMENT.

By Edward Bartow and J. M. Lindgren.

The water supplies of the University of Illinois and of the cities of Champaign and Urbana, Illinois, are obtained from wells about 160 feet deep. The water of the two supplies is of the same character and is similar to that from many wells throughout the state. The University of Illinois water may thus be considered as a type and results of experiments with it are applicable to many other waters of the state.

IONS.		HYPOTHETICAL COMBINATIONS		
PARTS PER MILLION			Parts per Million	Grains per Gallon
Potassium K	2.6	Potassium Nitrate KNO_3	1.1	.06
Sodium Na	29.0	Potassium Chloride KCl	2.9	.17
Ammonium NH_4	2.3	Sodium Chloride NaCl	3.5	.20
Magnesium Mg	34.9	Sodium Sulphate Na_2SO_4	3.6	.21
Calcium Ca	70.1	Sodium Carbonate Na_2CO_3	60.5	3.52
Iron Fe	1.0	Ammonium Car. $(NH_4)_2CO_3$	6.1	.36
Alumina Al	1.3	Magnesium Carbonate $MgCO_3$	121.2	7.07
Nitrate NO_3	.7	Calcium Carbonate $CaCO_3$	175.2	10.22
Chlorine Cl	3.5	Iron Carbonate $FeCO_3$	2.1	.12
Sulphate SO_4	2.3	Alumina Al_2O_3	2.5	.15
Silica SiO_2	18.9	Silica SiO_2	18.9	1.10
		Total	397.6	23.18

The water from the university wells, as shown by the analysis, contains small amounts of chlorides, nitrates and sulphates, and a considerable quantity of carbonates. The carbonates are combined with sodium, calcium, magnesium and iron.

On exposure to the air the water becomes turbid. A considerable quantity of sediment collects in the mains. This sediment varies in color from black to red according to the degree of oxidation of the iron salts. There is frequently trouble from crenothrix, and beggiatoa which is re-

sponsible for an unpleasant odor has been isolated. In boilers there is a formation of sludge or a soft scale which may clog the feed pipes. Corrosion of the joints and valves is frequent. Tea kettles are incrusted, and water backs in the ranges and furnaces are clogged by the water of the same character from the city supply.

Complaints in regard to the sediment have been made to the water survey by the departments of Dairy Husbandry and Photography, and the director of the gymnasiums complains of the character of the water in the swimming pools.

Experiments were undertaken in the State Water Survey laboratory to determine the possibility of remedying these evils.

The first experiments were performed by Mr. W. F. Wheeler during the summer of 1906.

Considering that a successful treatment would be indicated when the alkalinity to phenolphthalein was one half the alkalinity to methyl orange, varying amounts of lime were added to portions of the water, the precipitate was filtered off and alkalinity determined in the filtrate. It was found that considerably more lime was needed to obtain the relation of 1 to 2 than could be accounted for by the removal of salts of calcium and magnesium. We thougnt this due to the fact that the lime was added in powdered form, (prepared by treating lime with one-third its weight of water), and that a considerable residue of calcium hydroxide remained in the precipitate. Later experiments show this theory to be erroneous.

Determinations of the alkalinity to phenolphthalein and methyl orange at varying intervals up to twenty-four hours after the addition of the lime indicated that the reaction was practically complete in six hours. Beyond six hours, there was a slight reaction.

The second experiment, (by the writers), was with lime water instead of the dry lime. The theoretical amount was determined by analysis and then the treatment tried on a large scale, but the results were no nearer the theoretical than before.

The third experiment was planned in order to explain the action of the excess of lime and to determine, if possible, what actually took place during the treatment. A series of tests was arranged which would show the effect or varying amounts of lime on the alkalinity and also the effected reduction on salts of calcium and magnesium.

Into each of nineteen glass stoppered bottles of about two liters capacity was measured a liter of water, taken directly from the University well.

To each portion of water was added lime water, (10 c. c. of which was equivalent to 24 parts calcium carbonate) in increasing amounts from 24 to 720 parts per millon of calcium oxide (in terms of calcium carbonate.) Since the previous experiments showed that the reaction was practically completed at the end of six hours, it was decided to use this time period for the reactions. At the end of six hours the precipitate formed in each bottle was filtered off and the alkalinity to phenolphthalein and methyl orange and the magnesium and calcium content of the filtrates were determined.

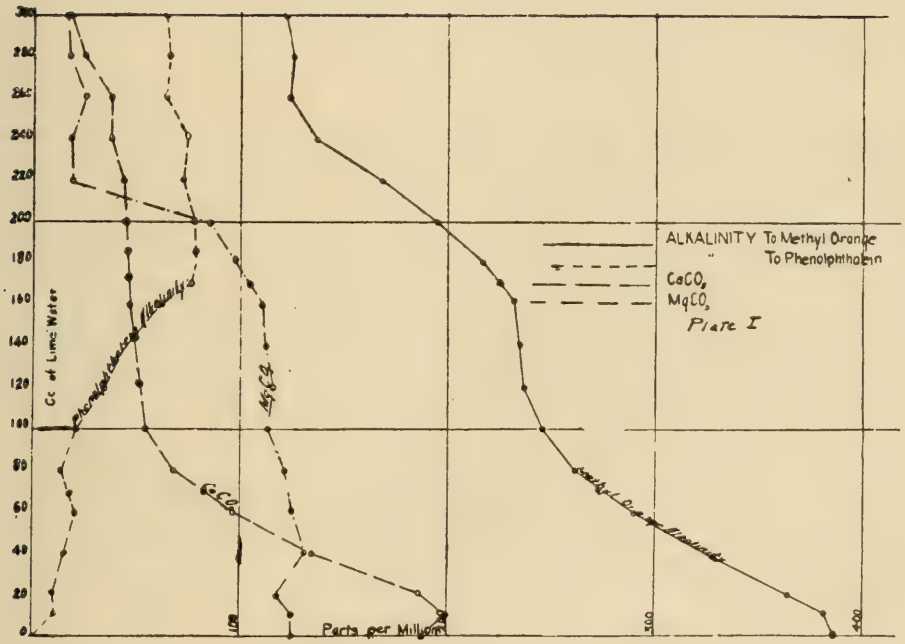
The results of the determination of the alkalinity and the content of calcium and magnesium are shown in table I and a diagramatic representation is shown on plate I. The alkalinity to methyl orange rises at first, then falls until 100 c. c., of the lime water was added, then remains constant for 60 c. c., then falls and finally rises. The calcium is shown to be removed for the most part on addition of the first 100 c. c., during which time the alkalinity to methyl orange falls. The magnesium is scarcely decreased until 200 c. c. of the lime water have been added, after which it is rapidly removed. Undoubtedly the reactions take place in order almost quantitatively, though some overlapping may be seen.

The first reaction is evidently between the lime water and the carbonic acid present. The second between the lime water and the calcium acid carbonate present, with the removal of calcium carbonate. The third reaction is the reaction between the lime water and sodium acid carbonate with the formation of sodium neutral carbonate, and the

TABLE NO. 1.

Treatment of the University of Illinois Water Supply With Lime.

No.	Lime Water	Amount of Lime Used	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium	
			Filtrate	Corrected for Volume	Filtrate	Corrected for Volume	CaO in 250 c. c.	$CaCO_3$ Cor. for Vol.	$Mg_2P_2O_7$ from 250 c. c.	As $MgCO_3$ Cor. for Vol.
	C. C.	Parts Per Million	Parts Per Million	Parts Per Million	Parts Per Million	Parts Per Million	Milligrams	Parts Per Million	Milligrams	Parts Per Million
1	0	0	0	0	387.5	387.5	26.5 mg.	188.7	33.1	124.4
2	10	24	11.5	11.7	378.0	381.8	27.5	198.6	33.2	126.0
3	20	48	10.5	10.7	354.9	361.9	25.8	187.5	33.8	118.0
4	40	96	16.8	17.5	312.9	325.4	18.0	133.9	36.0	131.6
5	60	144	18.9	20.1	270.9	287.1	12.9	97.4	40.5	126.0
6	70	168	12.6	13.5	256.2	274.1	10.8	82.3	39.4	126.0
7	80	192	12.6	13.6	241.5	260.8	9.0	69.0	37.3	121.6
8	100	240	18.9	20.8	222.6	244.9	7.1	54.9	34.2	113.6
9	120	288	31.5	35.3	212.1	237.6	6.6	52.6	34.5	116.0
10	140	336	42.0	47.9	203.7	232.2	5.3	43.2	32.7	112.0
11	160	384	52.5	60.9	200.5	232.6	5.7	46.2	31.9	110.8
12	170	408	65.1	76.2	193.2	226.0	5.7	46.7	30.4	105.2
13	180	432	66.3	78.2	184.8	218.1	5.7	48.4	27.8	99.6
14	200	480	65.1	78.1	163.8	196.6	5.5	46.7	23.4	84.4
15	220	528	58.8	71.7	138.6	169.1	5.1	43.9	5.3	19.2
16	240	576	58.8	72.9	111.3	138.0	4.5	39.7	5.2	19.2
17	260	624	52.5	63.3	98.7	124.4	4.4	38.9	7.7	27.6
18	280	672	50.4	64.5	98.7	126.3	7.0		5.0	19.2
19	300	720	48.3	62.8	94.5	122.8	6.3		4.8	19.2


ALKALINITY To Methyl Orange
To Phenolphthalein
CaCO3
MgCO3
Plate I
Cc of Lime Water
Parts per Million

precipitation of calcium carbonate. During this phase the alkalinity to methyl orange remains constant, the alkalinity to phenolphthalein alkalinity rises. The fifth stage is the reaction between the lime water and magnesium carbonate with the precipitation of magnesium hydrate and calcium carbonate, during which phase the alkalinity to both methyl orange and phenolphthalein decreases.

The series of tests shows the necessity of considering the sodium acid carbonate present, since it must be changed to the neutral carbonate before the magnesium is precipitated. These experiments also suggest the advisability of considering whether it would be profitable to remove both calcium and magnesium or only the calcium.

From table I we note that 71% of the carbonate of calcium or about 50% of the combined carbonates of calcium and magnesium are removed by 134 parts per million of calcium oxide, (240 parts per million as calcium carbonate), equivalent to 7.82 grains per gallon or 1.1 pounds per thousand gallons. On a basis of 50 cents per hundred as the price of lime, this treatment will cost 55-100 cents per thousand gallons.

If on the other hand it be desired to obtain the maximum (80%) removal of these compounds, it will be necessary to add 296 parts per million or 17.26 grains per gallon or 2.46 pounds per thousand gallons. This would more than double the cost with an increase of only 30% of carbonates removed.

To further test our results a water was chosen, which had a greater amount of sodium carbonate and less of the carbonates of calcium and magnesium.

An analysis of the water gave the following results:

IONS.		HYPOTHETICAL COMBINATIONS		
PARTS PER MILLION			Parts per Million	Grains per Gallon
Potassium K	4.9	Potassium Nitrate KNO_3	.6	.03
Sodium Na	84.4	Potassium Chloride KCl	9.0	.52
Ammonium NH_4	10.8	Sodium Chloride NaCl	15.2	.89
Magnesium Mg	30.1	Sodium Sulphate Na_2SO_4	4.4	.26
Calcium Ca	55.9	Sodium Carbonate Na_2CO_3	177.2	10.33
Iron Fe	6.6	Ammonium Car. $(NH_4)_2CO_3$	28.7	1.67
Alumina Al	1.4	Magnesium Carbonate $MgCO_3$	104.2	6.07
Nitrate NO_3	.4	Calcium Carbonate $CaCO_3$	139.5	8.13
Chlorine Cl	13.5	Iron Carbonate $FeCO_3$	13.7	.80
Sulphate SO_4	3.0	Alumina Al_2O_3	1.4	.08
Silica SiO_2	17.7	Silica SiO_2	17.7	1.03
Bases	.6	Bases	.6	.02
		Total	512.2	29.84

This water was treated with lime water using varying amounts as in the previous experiment. The results obtained with this water, are shown in table II and in diagramatic representation on Plate II. It will be noted that the curve representing alkalinity to methyl orange is of the same general character as on Plate I. The decrease of alkalinity during the precipitation of calcium is less. While the reaction is taking place between the lime and sodium bicarbonate the alkalinity does not vary and the corresponding line is longer, corresponding quite closely to the relative amounts of the sodium bicarbonate present in the two waters.

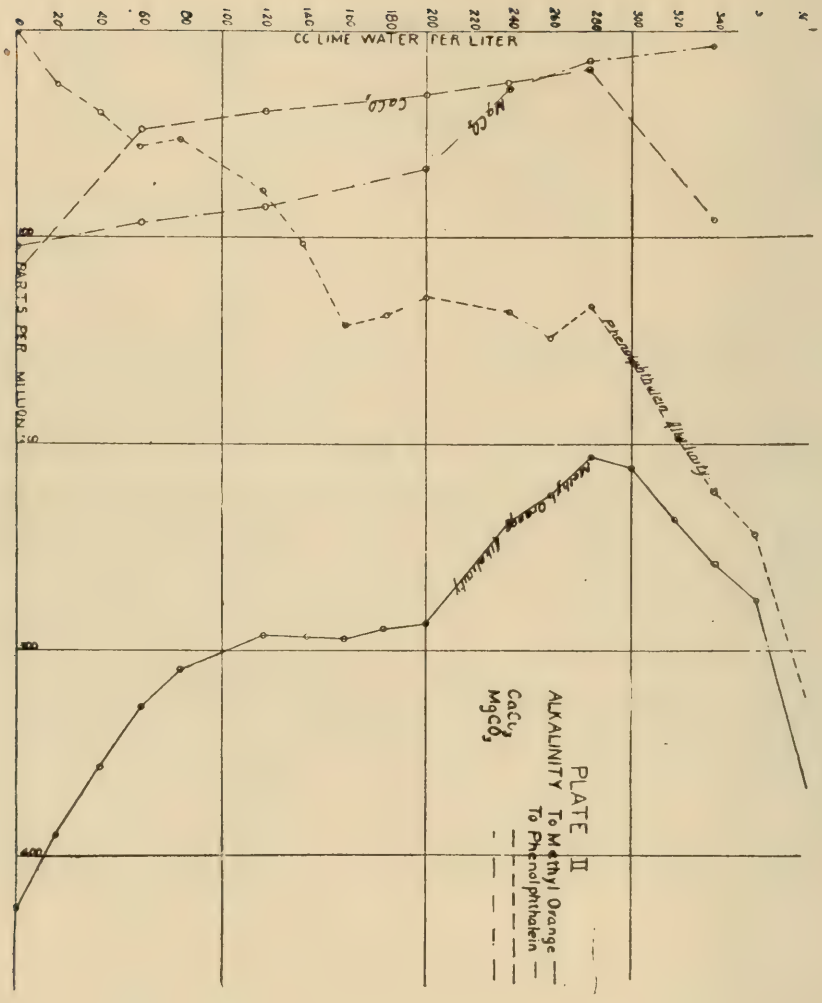

CC LIME WATER PER LITER
PARTS PER MILLION
CaCO3
MgCO3
Phenolphthalein Alkalinity
Methyl Orange Alkalinity
PLATE II
ALKALINITY To Methyl Orange
To Phenolphthalein
CaCO3
MgCO3

TABLE II.

Treatment of Water from Deep Well of Illinois Hotel Co., Bloomington, Illinois, with Lime.

No.	Lime Water Cubic Centimeters	Amount of Lime Used Milligrams per Liter	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium	
			Filtrate Parts per Million	Corrected for Volume Parts per Million	Filtrate Parts per Million	Corrected for Volume Parts per Million	CaO in 250 c. c. Milligrams	$CaCO_3$ Cor. for Volume Parts Per Million	$Mg_2P_2O_7$ From 250 c. c. Milligrams	As $MgCO_3$ Cor. for Volume Parts Per Million
1	0	0	.0	.0	423.	423.	9.	118.1		
2	5	44	25.0	26.0	378.	386.				
3	10	88	38.	39.	343.	357.				
4	15	132	52.	56.	309.	327.	5.3	49.9	23.6	93.8
5	20	176	48.4	52.	287.	310.				
6	30	264	69.	78.	261.	292.	3.4	33.9	20.1	85.2
7	35	308	90.	103.	256.	292.				
8	40	352	122.	141.	254.	295.	3.0	30.9	18.8	82.4
9	45	396	118.	139.	245.	290.				
10	50	440	108.	129.	239.	287.	3.0	31.9	14.8	67.2
11	60	528	109.	135.	192.	237.	2.2	24.2	6.2	29.1
12	65	572	118.	148.	179.	225.				
13	70	616	104.	133.	162.	207.			2.4	14.5
14	75	660	124.	161.	162.	210.				
15	80	704	147.	194.	178.	236.				
16	85	748	166.	222.	194.	259.	7.8	92.	1.8	9.0
17	90	792	178.	243.	202.	274.				
18	100	880	242.	338.	267.	373.				

In this case an amount of lime equal to 74 parts per million or 4.31 grains per gallon or 6 lb for 1000 gallons, removed 58% of the calcium carbonate or 35% of the combined carbonates of magnesium and calcium. The cost of this removal would be 3/10 of a cent per 1000 gallons.

In order to reach the highest efficiency, a removal of 82% of the combined carbonates, it would be necessary to add 345 parts per million of pure lime equivalent to 20.1 grains per gallon or 2.86 pounds per thousand gallons.

To try to determine the correctness of our hypothesis, that the sodium bicarbonate interferes with the precipitation of magnesium by means of lime, we substituted sodium hydroxide for calcium oxide in a similar series of tests. The solution of sodium hydroxide was made of ten times the strength of the lime water, and 1/10 the amount was used in each case. Adding such a small amount of the solution, no correction was made for dilution. The results obtained are shown in Table III and are diagramatically represented on Plate III. An inspection of the results shows that the calcium acid carbonate is removed with one-half of an equivalent amount of sodium hydroxide; that the alkalinity to methyl orange decreases slightly until the calcium is removed, after which it increases steadily; and that the magnesium is removed at about the same time, as with calcium oxide, but more slowly. The results confirm the hypothesis that the sodium acid carbonate delays the precipitation of magnesium. A comparison of Plates I and III would indicate that there would be no advantage in using sodium hydroxide rather than lime to soften a water like the University of Illinois supply. The calcium acid carbonate would be removed with the formation of less sludge, but the increase in soluble residue would more than offset this advantage.

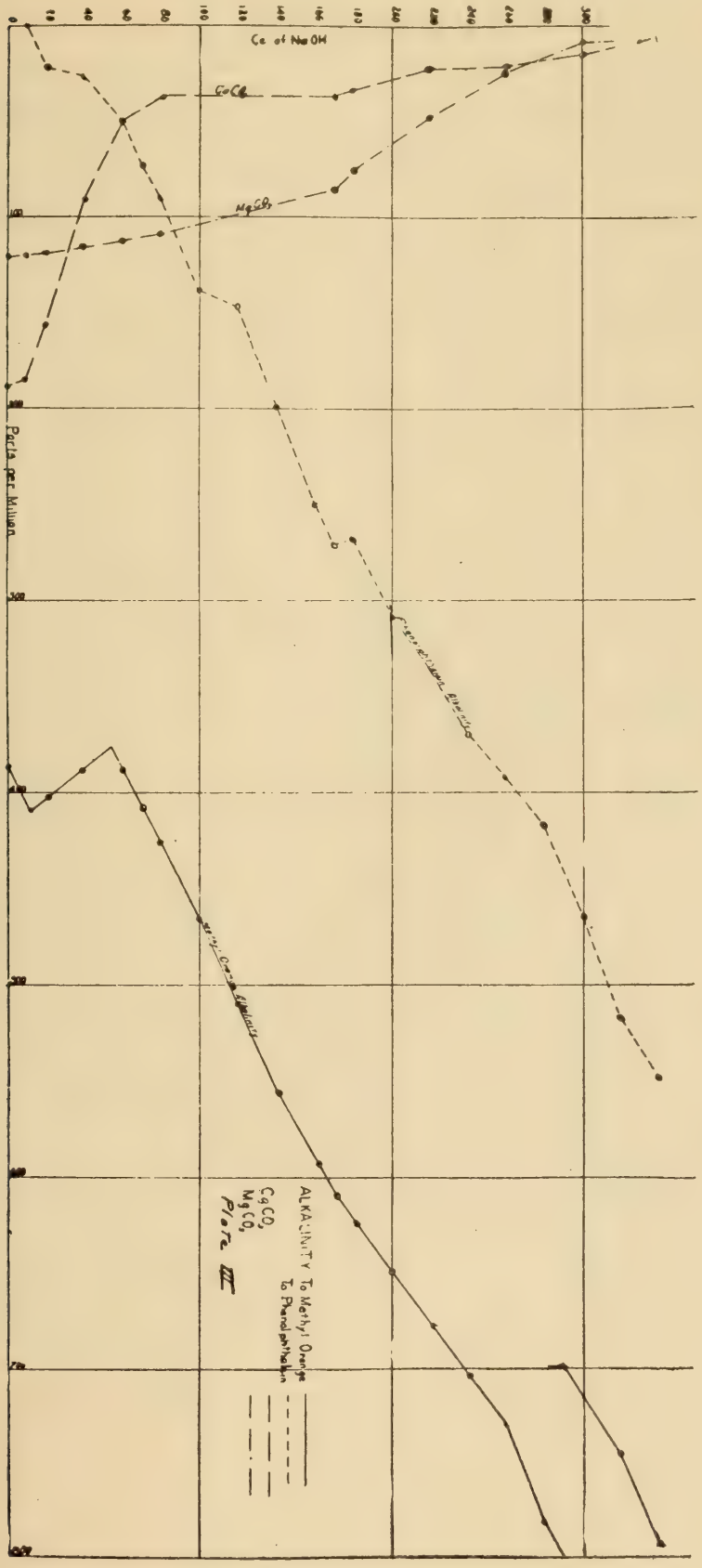

Cc of NaOH
CaCO3
MgCO3
Parts per Million
ALKALINITY To Methyl Orange
To Phenolphthalein
CaCO3
MgCO3
Plate III

TABLE III.

Treatment of the University of Illinois Water Supply with Sodium Hydroxide.

No.	Sodium Hydroxide Solution c. c.	Amount of Sodium Hydroxide Used Milligrams	Alkalinity to Phenolphthalein Parts per Million	Alkalinity to Methyl Orange Parts per Million	Calcium		Magnesium	
					CaO in 250 c. c. Milligrams	$CaCO_3$ Parts per Million	$Mg_2P_2O_7$ From 250 c. c. Milligrams	$MgCO_3$ Parts per Million
1	0	0	0	386.	26.5	189.1	39.7	120.5
2	1	17	0.	405.	26.0	185.5	39.8	120.5
3	2	34	22.	403.	22.1	157.8	38.3	118.8
4	4	68	26.	388.	12.8	91.3	38.1	118.4
5	6	102	50.	388.	7.2	50.4	37.4	113.2
6	7	119	72.	406.				
7	8	136	90.	426.	5.4	38.4	36.1	109.4
8	10	170	139.	468.				
9	12	204	147.	511.				
10	14	238	198.	555.				
11	16	272	248.	589.				
12	17	299	270.	609.	5.4	38.4	28.5	86.2
13	18	316	266.	622.	4.5	32.0	25.3	76.5
14	20	340	307.	650.				
15	22	374	334.	673.	3.0	21.2	15.8	47.8
16	24	408	369.	702.				
17	26	442	393.	728.	2.9	20.5	6.8	20.4
18	28	476	417.	780.				
19	30	510	463.	813.	2.1	15.0	3.2	9.7
20	32	544	518.	845.				
21	34	578	549.	893.	.8	5.5	2.2	6.6

Since the waters of the State of Illinois may be hypothetically divided into two classes, those containing sodium carbonate and those containing magnesium sulphate, we next experimented with a magnesium sulphate water.

For this purpose we chose a water from a shallow well at the plant of the Dean & Bode Manufacturing Co., Champaign, Illinois. This water forms a hard scale when used in boilers, and is another type of water common in this State. An analysis of the water follows:

IONS		HYPOTHETICAL COMBINATIONS		
PARTS PER MILLION			Parts per Million	Grains per Gallon
Sodium Na	33.4	Sodium Nitrate $NaNO_3$	1.6	.09
Magnesium Mg	50.0	Sodium Chloride NaCl	39.6	2.31
Calcium Ca	106.9	Sodium Sulphate Na_2SO_4	53.7	3.13
Oxide of Iron and Alumina	2.2	Magnesium Sulphate $MgSO_4$	145.7	8.49
Nitrate NO_3	1.2	Magnesium Carbonate $MgCo_3$	36.4	2.12
Chloride Cl	24.0	Calcium Carbonate $CaCO_3$	266.8	15.56
Sulphate SO_4	152.5	Oxide of Iron Fe_2O_3 + and Alumina Al_2O_3	2.2	.13
SiO_2	11.0	Silica SiO_2	11.0	.64
Bases	3.0	Bases	3.0	.17
		Total Mineral Matter	560.0	32.64

The first experiment with the magnesium sulphate water was carried out in the same way as the first experiment with the sodium carbonate water. The results are shown in Table IV, with a diagramatic representation on Plate IV. An inspection of Plate IV shows that the first reaction is between the lime water and the free carbon dioxide. The second is the removal of calcium carbonate. The third is evidently a neutralization of magnesium acid carbonate and the change from magnesium sulphate to calcium sulphate. The fourth is a decrease in the magnesium content

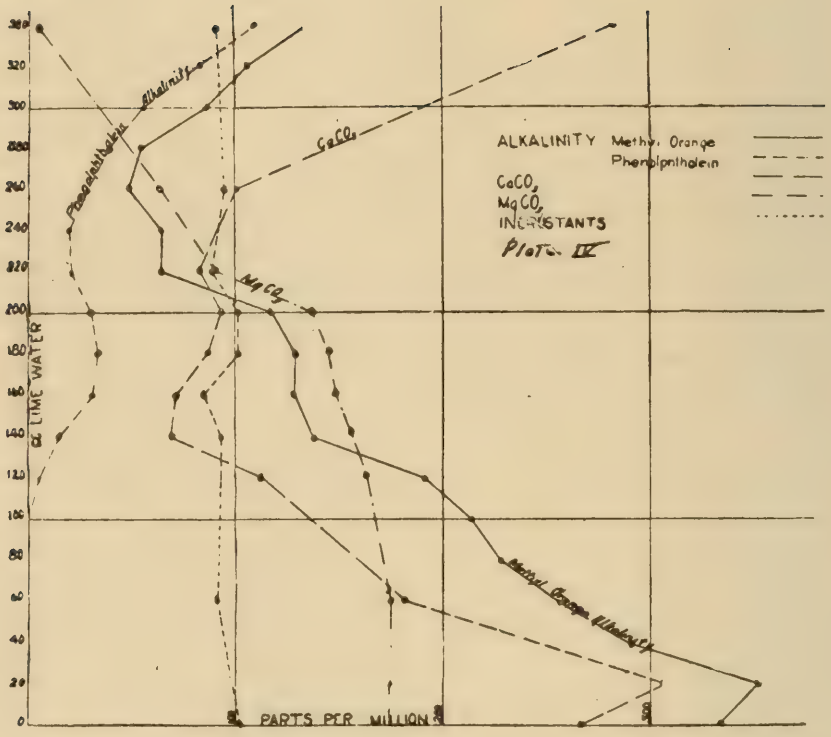

ALKALINITY Methyl Orange
Phenolphthalein
CaCO3
MgCO3
INCRUSTANTS
Plate IV
CaCO3
MgCO3
Phenolphthalein Alkalinity
Methyl Orange Alkalinity
G. LIME WATER
PARTS PER MILLION

TABLE IV.

Treatment of Water From Shallow Well, Champaign, Illinois, With Lime.

No.	Lime Water Used c. c.	Amount of Lime Used	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants
			Filtrate	Corrected for Volume	Filtrate	Corrected for Volume	CaO in 250 c. c.	$CaCO_3$ Cor. for Vol.	$Mg_2P_2O_7$ From 250 c. c.	As $MgCO_3$ Cor. for Vol.	
		Milligrams	Parts Per Million	Parts Per Million	Parts Per Million	Parts Per Million	Milligrams	Parts Per Million	Milligrams	Parts Per Million	Parts Per Million
1	0	0	0	0	332	332	37.4	266.4	57.1	173.1	103.9
2	20	41	0	0	345	351	42.3	307.6	56.5	174.5	
3	40	82	0	0	279	290					
4	60	124	0	0	236	255	24.0	181.6	53.6	174.5	91.7
5	80	165	0	0	209	228					
6	100	206	0	0	191	214					
7	120	247	6.4	7.4	169	191	14.4	114.8	48.8	164.8	93.0
8	140	287	11.9	13.6	118	137	8.5	68.8	45.6	157.9	94.6
9	160	330	25.7	31.0	110	128	8.6	70.8	42.2	148.2	85.4
10	180	371	29.4	35.	108	128	10.4	86.8	41.3	146.8	102.0
11	200	412	25.7	31.	94	118	11.1	93.8	38.1	137.1	104.0
12	220	453	18.3	22.	53	64	9.5	82.8	24.1	90.0	89.8
13	240	494	16.5	20	51	64					
14	260	536	23.0	29	39	48	11.3	99.6	15.8	63.6	95.0
15	280	577	31.2	40	42	54					
16	300	618	41.	54	66	86					
17	320	659	62.4	82	83	104					
18	340	700	82.6	110	101	133	29.6	282.5	1.3	5.5	91.2

An additional determination of incrustants was made on the water. The incrustants remained constant throughout the series, the amounts of calcium never decreased below 69 parts per million and the calcium increased as the magnesium decreased probably replacing the magnesium in the sulphate. In a water of this class no advantage is obtained by adding more than sufficient lime to remove the carbonates.

A discussion of the comparative cost of removing the calcium carbonate and total alkalinity would therefore be superfluous. The maximum amount of lime, if used alone, would be 161 parts per million, 9.39 grains per gallon or 1.3 pounds per thousand gallons.

A similar series of tests was made using a solution of sodium carbonate of the same strength as the lime water. The results of this experiment are shown in Table V, and are represented diagramatically on Plate V. In the first stage of the reaction the free carbon dioxide reacts with the sodium carbonate; in the second stage the incrustants decrease at the same time the calcium carbonate decreases. During the remainder of the series, there were no important changes, the magnesium carbonate remaining constant throughout the entire series. This experiment would show that it is profitable to treat this type of water with sodium carbonate alone, but that the amount should not exceed a quantity sufficient to remove incrustants and calcium carbonate. An excess should be avoided as the alkalinity would be increased and at the same time there would be an increase in the soluble residue which would make the treated water liable to foam.

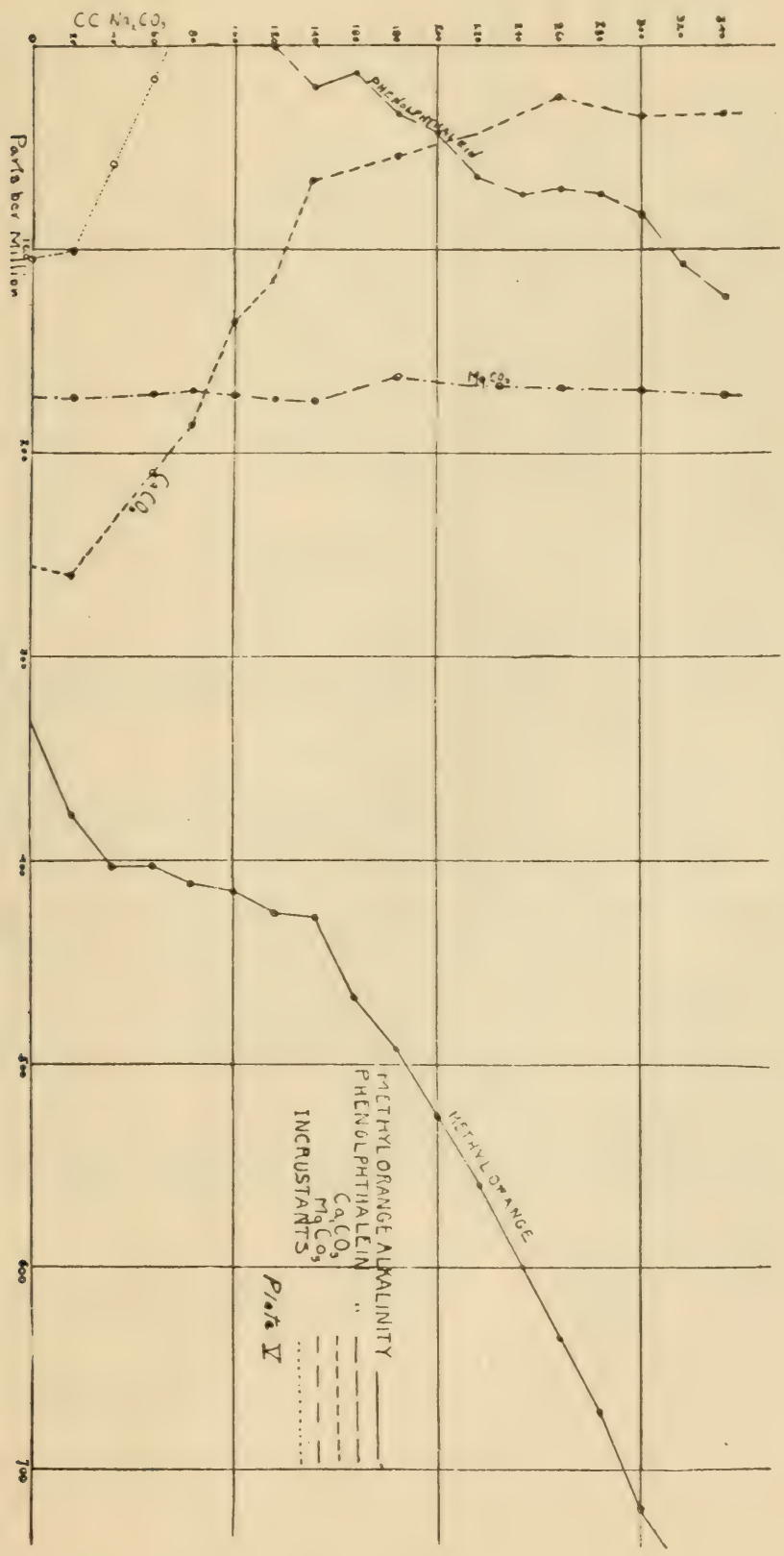

CC Na_2CO_3
Parts per Million
Phenolphthalein
Ca_2CO_3
Mg_2CO_3
METHYL ORANGE
METHYL ORANGE ALKALINITY
PHENOLPHTHALEIN "
Ca_2CO_3
Mg_2CO_3
INCRUSTANTS
Plate V

TABLE V.

Treatment of Water From Shallow Well at Champaign, Illinois, With Sodium Carbonate.

No.	Sodium Carbonate Solution c. c.	Amount of Sodium Carbonate Used	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants
			Filtrate	Corrected for Volume	Filtrate	Corrected for Volume	CaO in 250 c. c.	$CaCO_3$ Corrected for Volume	$Mg_2P_2O_7$ from 250 c. c.	As $MgCO_3$ Cor. for Volume	
		Milligrams	Parts Per Million	Parts Per Million	Parts Per Million	Parts Per Million	Milligrams	Parts Per Million	Milligrams	Parts Per Million	Parts per Million
1	0	0	0	0	334	334	36.1	257.6	57.3	173.2	103.9
2	20	22	0	0	369	376	39.4	260.4	56.6	174.3	101.0
3	40	44	0	0	391	404					59.
4	60	66	0	0	380	402	28.1	212.4	53.3	170.4	16.
5	80	88	0	0	380	411	25.7	166.8	51.8	169.0	
6	100	110	0	0	376	415	16.1	135.6	51.0	170.4	-67.
7	120	132	0	0	380	426	14.4	114.8	51.0	173.2	-91.
8	140	154	18	20	374	428	7.8	64.0	50.2	173.2	
9	160	176	11	13	404	468					-206.
10	180	198	29	33	417	492	6.7	52.8	45.5	162.1	-221.
11	200	220	35	42	437	525					-280.
12	220	242	53	64	457	558	4.9	42.8	45.5	167.6	-279.
13	240	264	59	72	481	597					-358.
14	260	286	55	70	503	633	3.1	28.8			-426.
15	280	308	57	73	525	672					-411.
16	300	330	61	83	556	722	3.9	34.0	43.1	169.	-475.
17	320	352	81	106	569	751					-620.
18	340	374	92	121	590	789	3.4	31.6	42.3	170.4	-561.

The maximum amount of sodium carbonate is 154 parts per million, 9 grains per gallon, 1.3 pounds per thousand gallons.

From the results of the two preceding experiments it was decided to combine the treatments using both sodium carbonate and lime. Therefore, a series of tests was carried out using in each test an amount of sodium carbonate which would a little more than neutralize the incrustants and varying the amounts of lime, as in the preceding experiments. The results of this experiment are shown in Table VI and are represented diagramatically on Plate VI. In this case the carbonate of calcium is reduced to a minimum more quickly than when the water was treated with lime alone. The calcium content, does not increase during the removal of the magnesium. The magnesium is precipitated at about the same point as when lime alone is used, though it comes out more rapidly than in the former case. The incrustants are shown to be negative, indicating that a slight excess of sodium carbonate was used. For this water the 106 parts per million of sodium carbonate or .88 pounds per 1000 gallons with 101 parts per million of lime or .84 pounds per 1000 gallons removed 70% of the calcium acid carbonate and 46% of the combined carbonates of calcium and magnesium. In order to obtain the maximum removal of alkaline earth carbonates (82%), 282 parts per million of pure calcium oxide would be required, equivalent to 16.44 grains per gallon or 2.3 pounds per thousand gallons for lime and 106 grains per gallon or .88 pounds per 1000 gallons of soda ash, making it cost for the removal of the calcium carbonate 1.2 cents per thousand gallons, or for combined carbonates, 2 cents per thousand gallons.

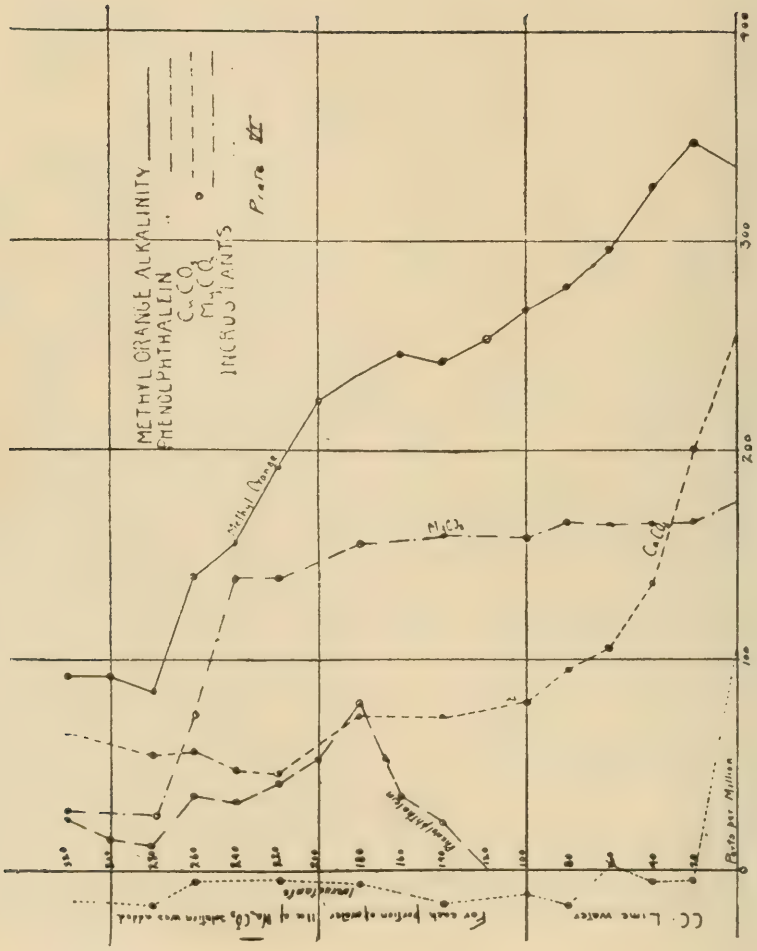

METHYL ORANGE ALKALINITY
PHENOLPHTHALEIN
CaCO3
Mg(OH)2
INCRUSTANTS
Plate XX
Methyl Orange
Mg(OH)2
CaCO3
Phenolphthalein
Parts per Million
CC. Lime water

TABLE VI.

Treatment of Water From Shallow Well, Champaign, Illinois, With a Constant Amount of Sodium Carbonate, and Varying Amounts of Lime.

No.	Lime Water Used c. c.	Amount of Lime Used	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants
			Filtrate	Corrected for Volume	Filtrate	Corrected for Volume	CaO in 250 c. c.	$CaCO_3$ Corrected for Volume	$Mg_2P_2O_7$ From 250 c. c.	As $MgCO_3$ Corrected for Volume	
		Milligrams	Parts Per Million	Parts Per Million	Parts Per Million	Parts Per Million	Milligrams	Parts Per Million	Milligrams	Parts Per Million	Parts Per Million
1	0	0	0	0	334	334	37.4	266.4	57.1	173.1	103.9
2	20	36	0	0	340	347	18.0	200.0	43.2	165.0	- 5.7
3	40	72	0	0	312	324	14.4	133.5	32.7	167.5	- 5.8
4	60	108	0	0	279	296	11.2	106.0	41.3	164.0	0.
5	80	144	0	0	257	278	9.8	95.0	41.1	168.	-19.
6	100	180	0	0	242	266	8.1	79.5	38.0	157.5	-13.2
7	120	216	0	0	224	251					
8	140	252	20	23	211	241	7.1	72.5	37.0	159.5	18.2
9	160	288	29	34	211	245					
10	180	324	62	79	200	236	6.9	72.5	34.3	154.0	9.4
11	200	360	44	53	185	222					
12	220	396	33	40	158	192	5.2	46.0	29.8	137.0	- 6.8
13	240	432	26	32	126	156	5.3	47.0	29.8	138.5	- 6.9
14	260	468	28	35	110	139	6.4	57.0	15.9	75.0	- 7.0
15	280	504	9	11.5	66	84	4.9	53.5	5.2	24.0	-18.0
16	300	540	11	14	70	91					
17	320	576	18	24	70	92	5.4	64.5	6.0	29.5	-15.8

Note—To each portion of water 11 c. c. of sodium carbonate solution containing 116.6 milligrams Na_2CO_3 was added.

SUMMARY.

Our work shows First: In a water containing sodium acid carbonate, allowance must be made for this substance when the water is treated with lime.

Second: Owing to the action of sodium bicarbonate on lime, it might pay to consider partial treatment to remove calcium carbonate alone, rather than complete treatment to remove magnesium carbonate also.

Third: Treatment of magnesium sulphate waters with lime alone is unsatisfactory since the sulphate of calcium remains in the solution.

Fourth: Treatment of a magnesium sulphate water with sodium carbonate alone is satisfactory if only carbonate of calcium is removed and the incrustants neutralized.

Fifth: That treatment of a magnesium sulphate water with sodium carbonate and calcium hydrate shows similar reactions to the treatment of the sodium carbonate water and that a consideration of the relative cost of partial and complete treatment is advisable.

Sixth: When it is not practicable to treat all of a supply, information as to the exact character of the water and the best method of treatment should be furnished to consumers.

DISCUSSION.

MR. MONFORT: I have listened with a great deal of interest to the abstract of the paper. The data presented is in line with a good deal of my own observation. At present my observation is not complete, and I trust at some later time to be able to compare notes with the authors of the paper. I desire now to express what I think is the feeling of the Association, our appreciation of the honor paid us in presenting the paper here.

Obituary

COL. J. T. FOSTER

Died at his Home in Chicago, Ill., March, 1907, Aged Seventy-nine.

Colonel Foster was one of the few left of that little band of twenty-five who organized the American Water Works Association at St. Louis in 1881. He was elected the first presiding officer of the young association; and was elected its first President, being re-elected for a second term at Columbus, Ohio, in 1882. Thus Colonel Foster is the only one to have twice been elected president of this association.

That he was well qualified for the position is well known, being one of the foremost water works engineers of the day, a day when there were few engineers devoting their talents to water supply.

Colonel Foster has always remained an enthusiastic member of the association, contributing much to its success and growth, in the way of papers, discussions and wise council. His loss is a serious one to the engineering profession, as well as to the American Water Works Association.

His title of Colonel was earned in the war of 1861-65, in which he served for four years. He organized and took to the front the La Crosse (Wisconsin) Battery, serving with it and in other capacities during the entire war.

Obituary

JOSEPH A. BOND

Died at Wilmington, Del.,

May 23, 1907.

Aged Sixty-nine years.

To the older members of this association, Mr. Bond was well known, having joined it in 1888, and never missing one of the annual conventions, in which he always took an active part. He was elected president at Buffalo in 1898.

Mr. Bond was born at Radford, Pa., and was educated at the State University of Michigan, at Ann Arbor. After graduating, he engaged in teaching till the breaking out of the war, when he joined one of the Pennsylvania emergency regiments.

After the war, he settled in Wilmington, Del., in which city he was appointed clerk in the Water Department, of which he soon became the chief engineer, which position he held till compelled by poor health to give it up, having held the office for over twenty years.

At the time of his death, Mr. Bond was serving the State of Delaware as Factory Inspector.

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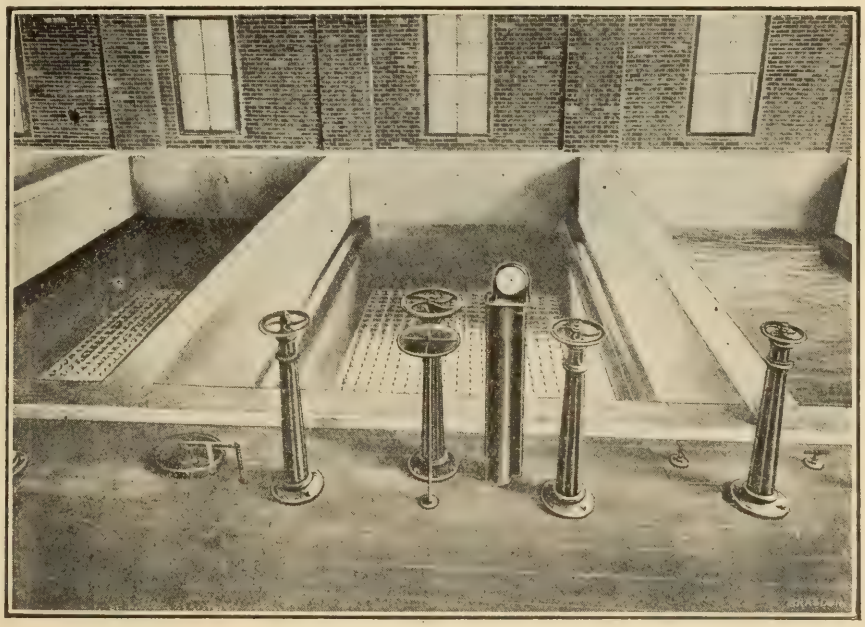

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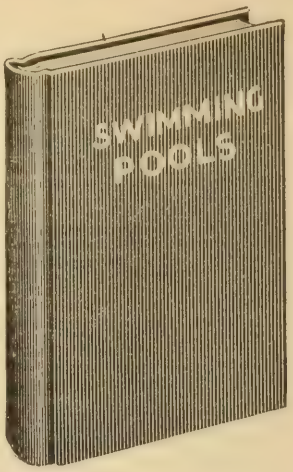

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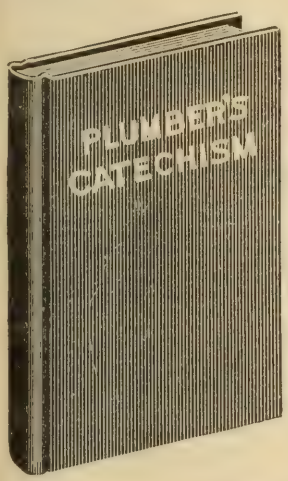

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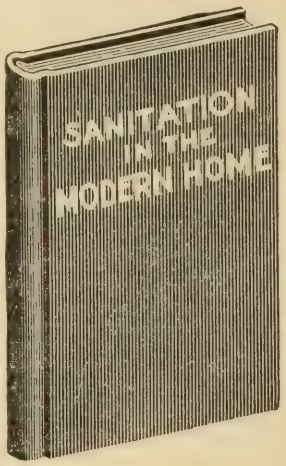

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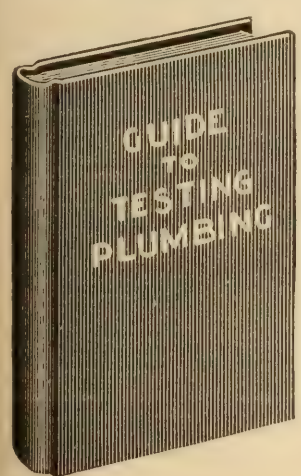

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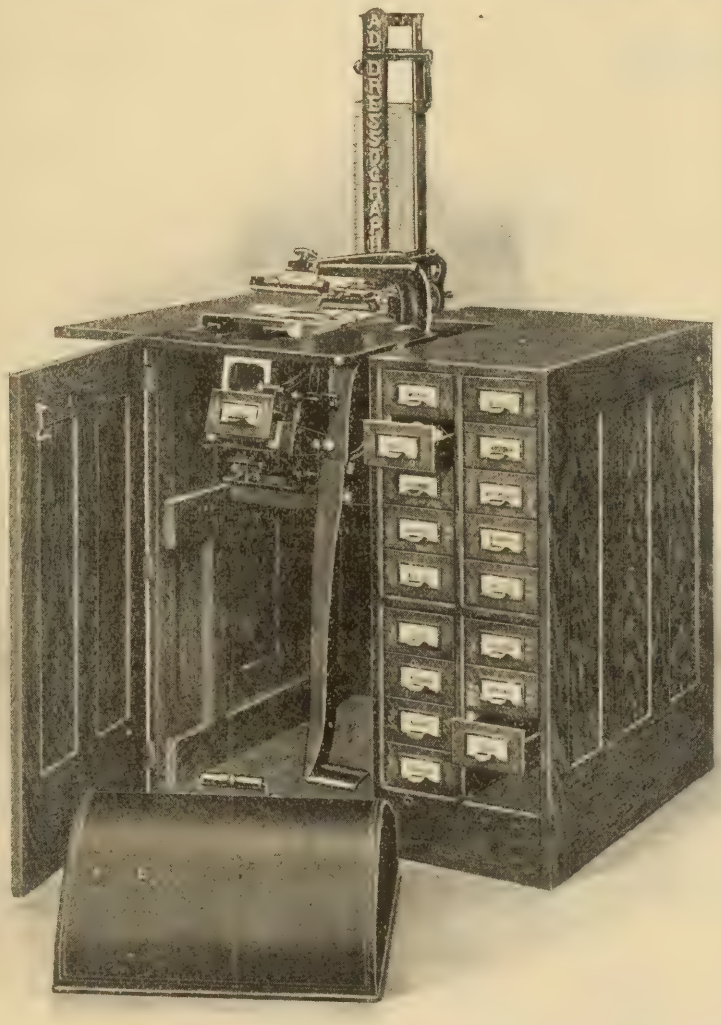

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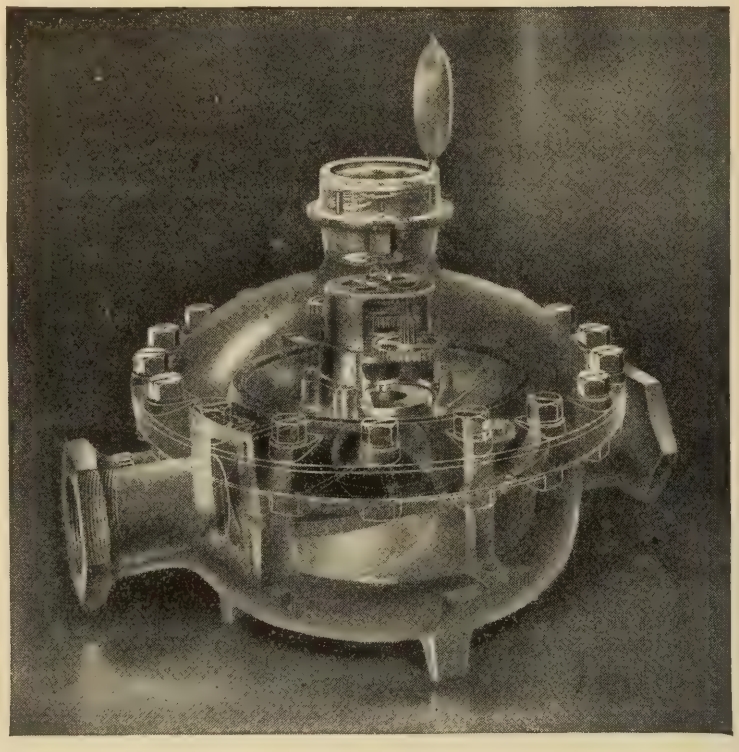

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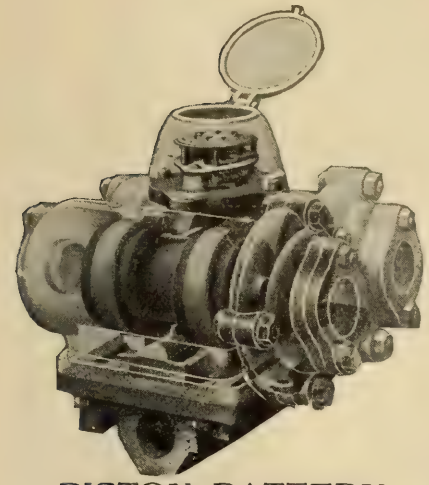

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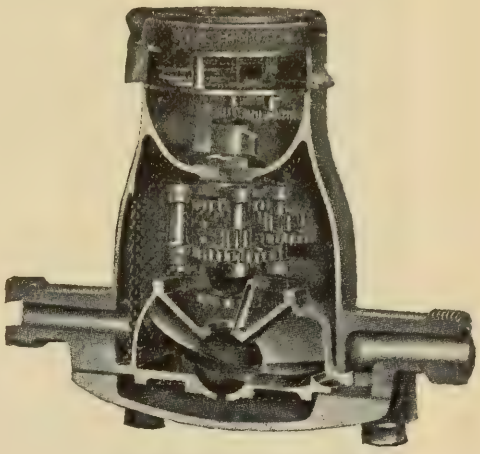

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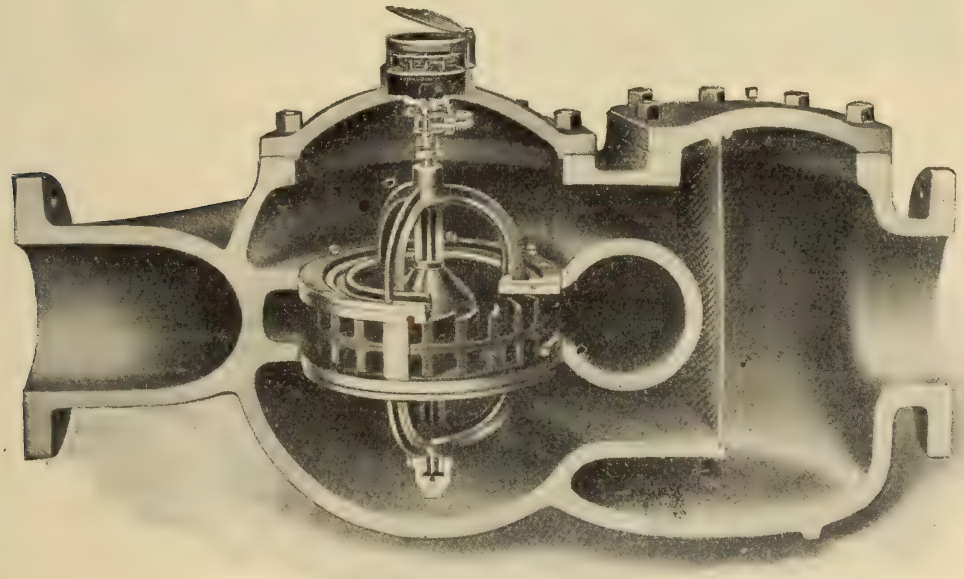

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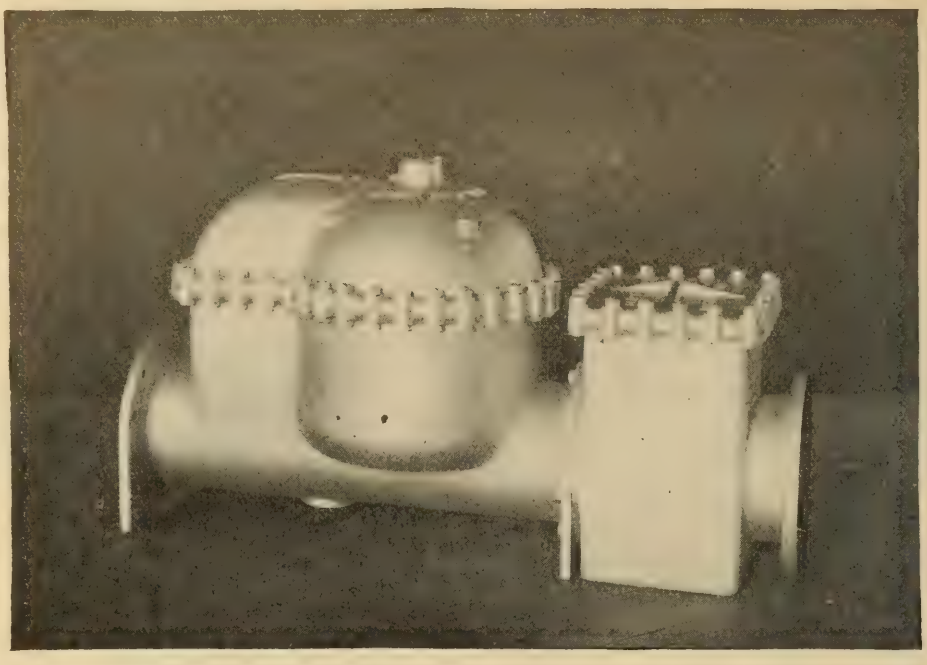

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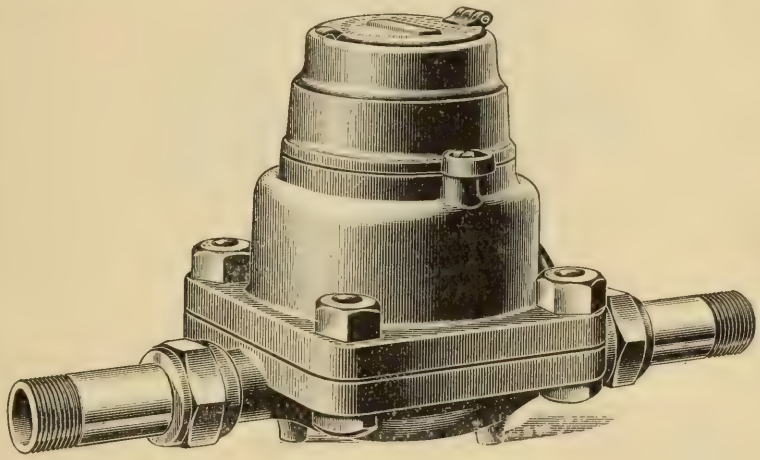

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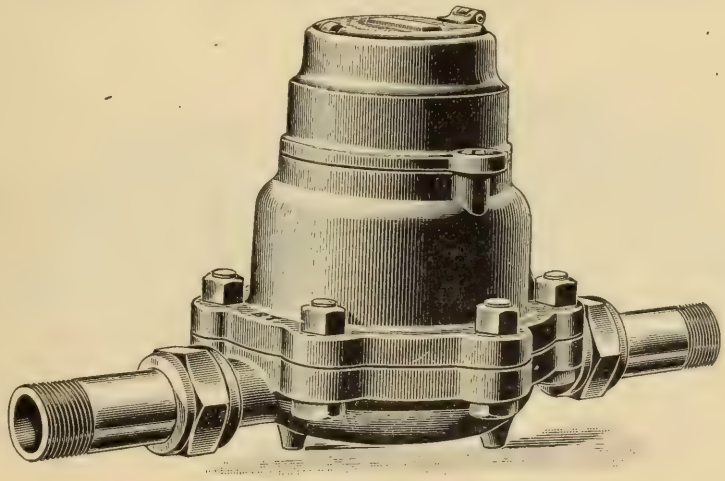

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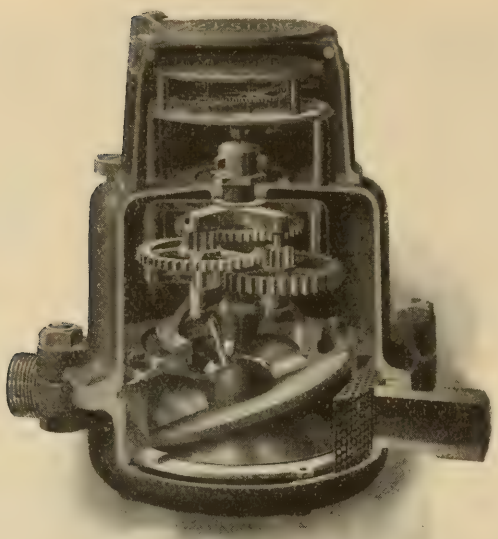

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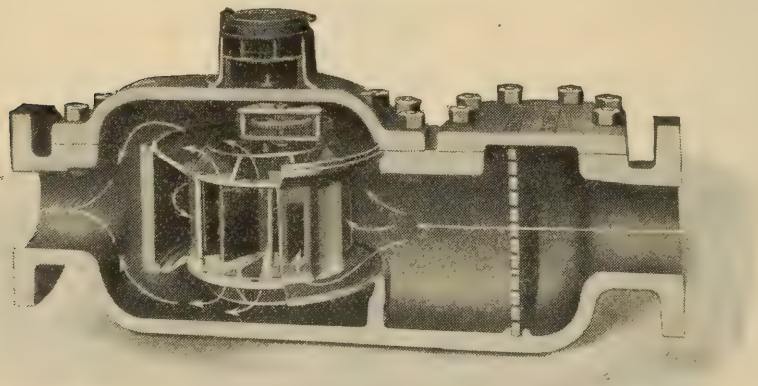

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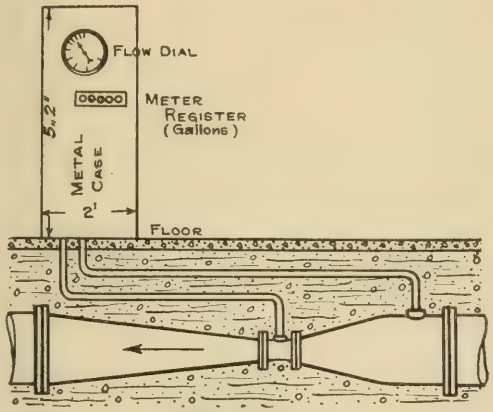

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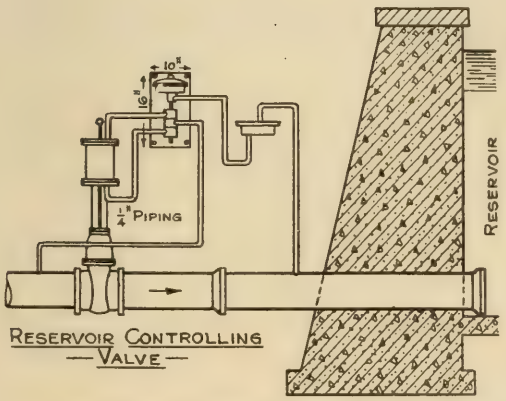

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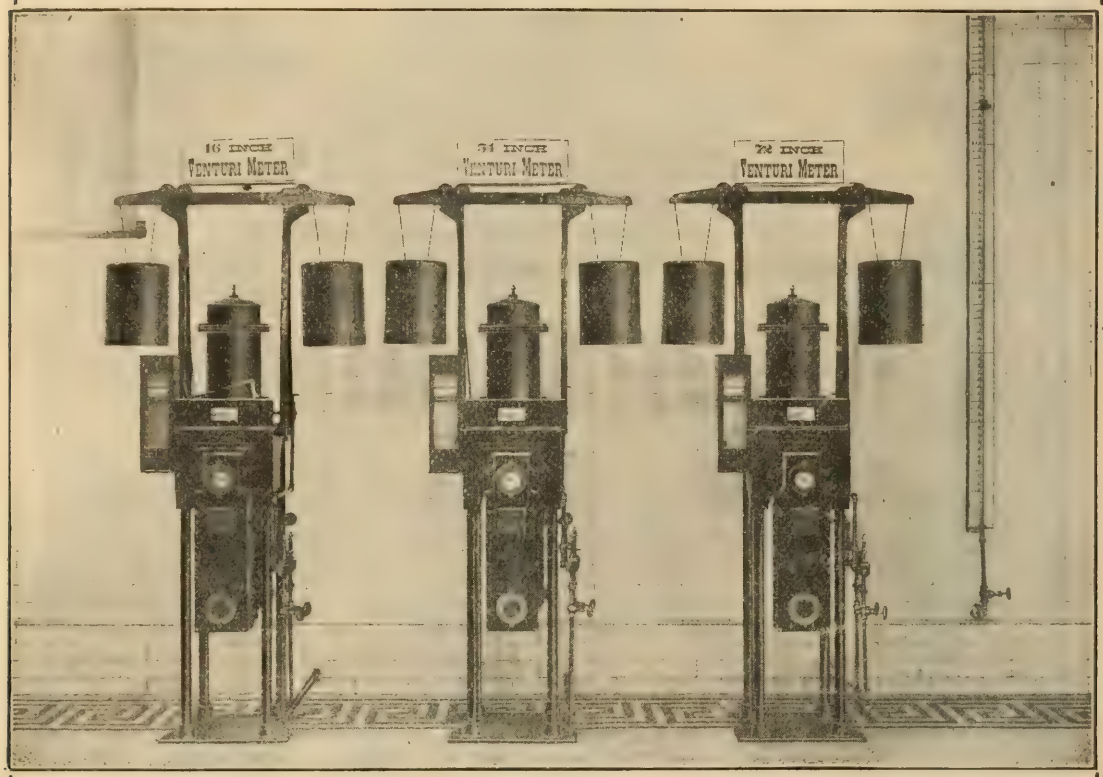

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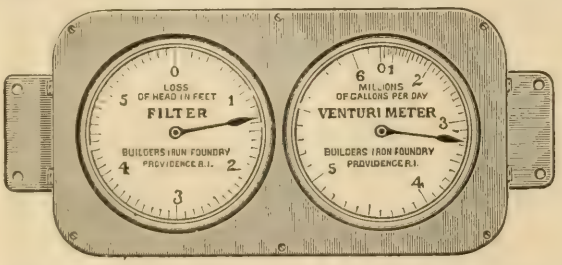

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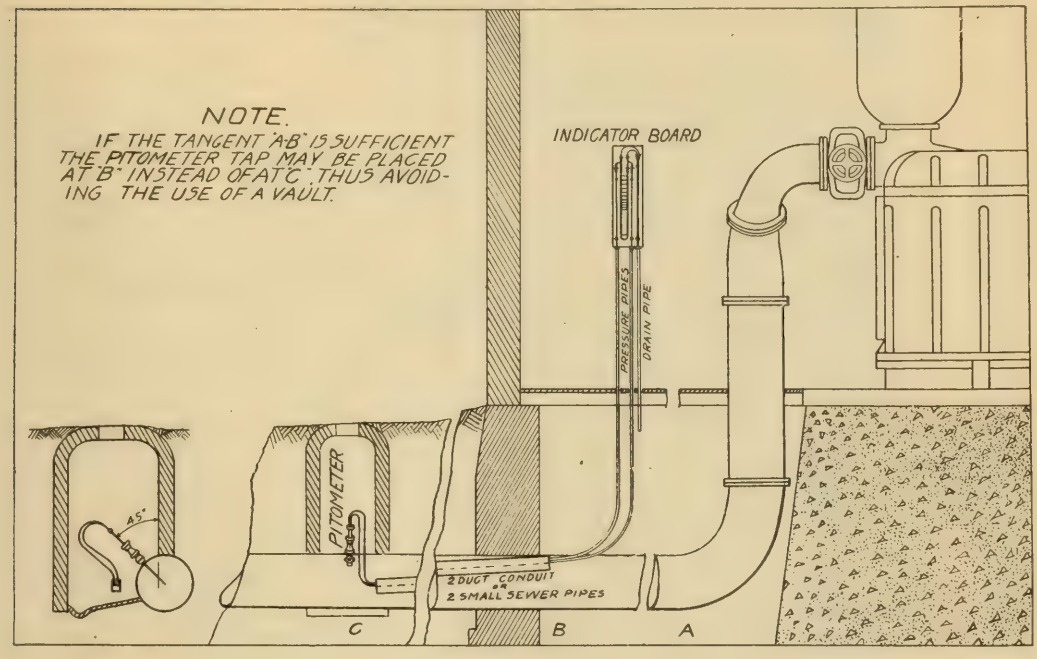

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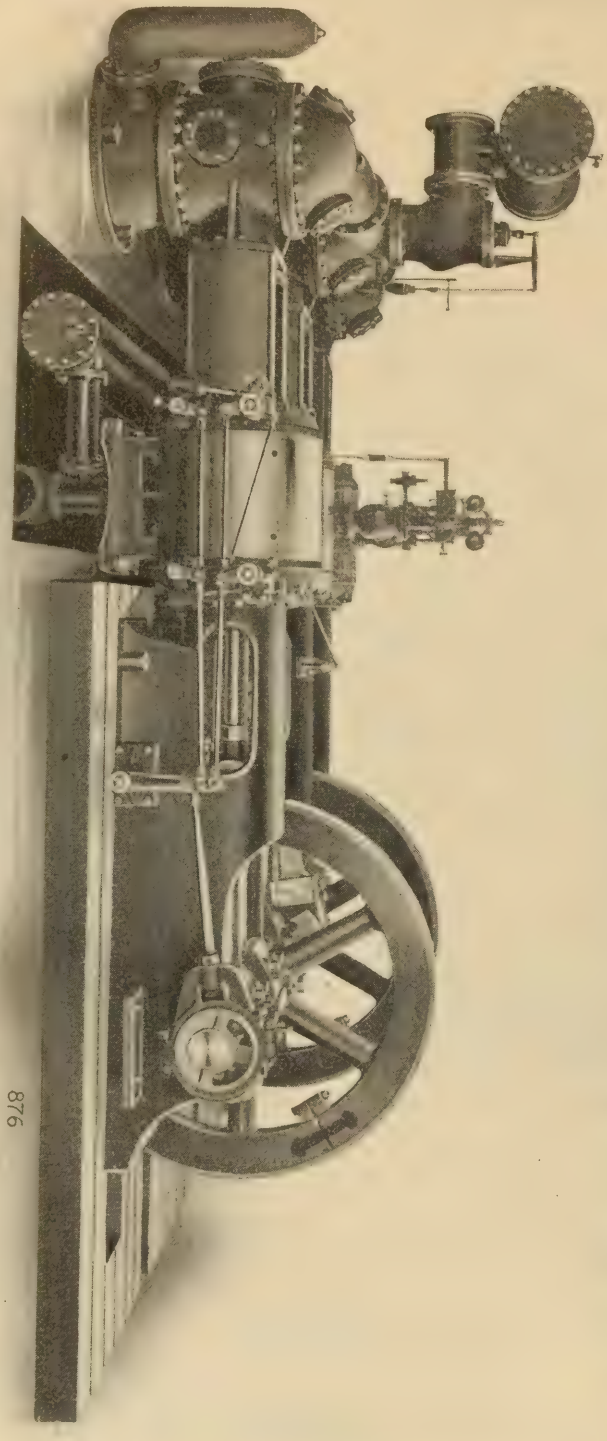

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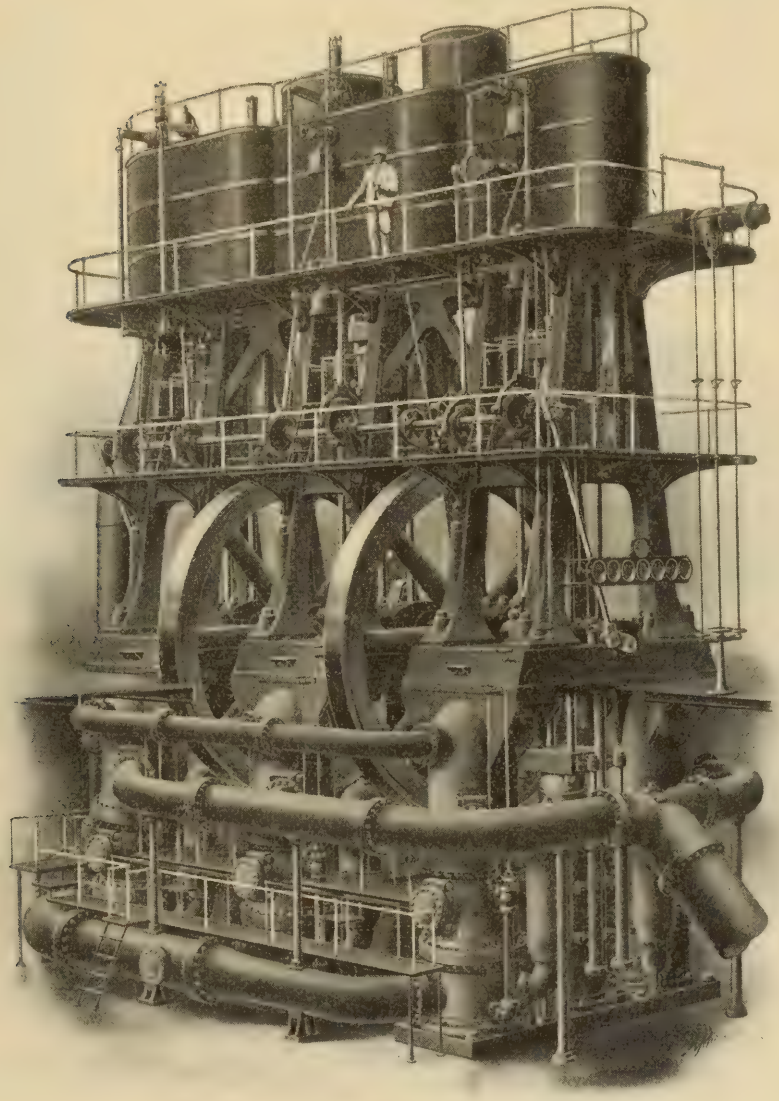

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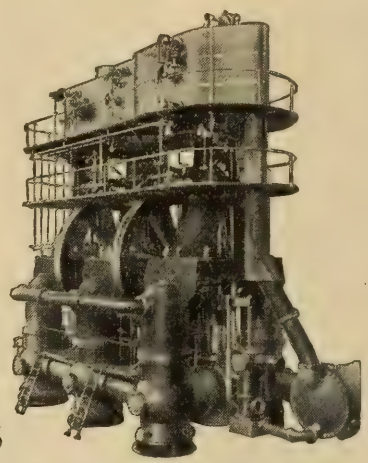

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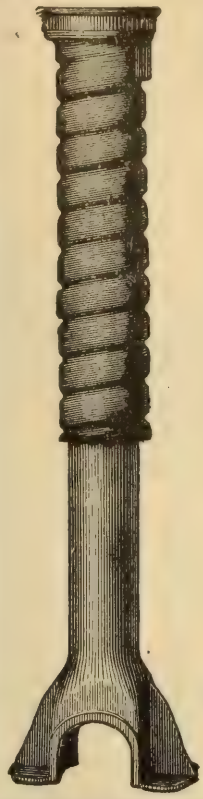

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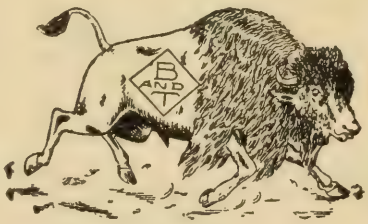

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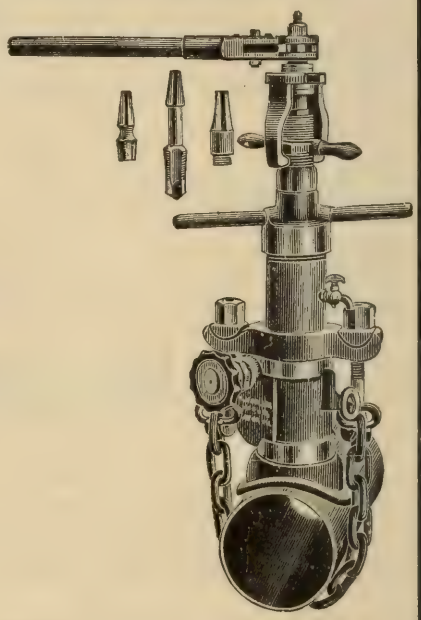

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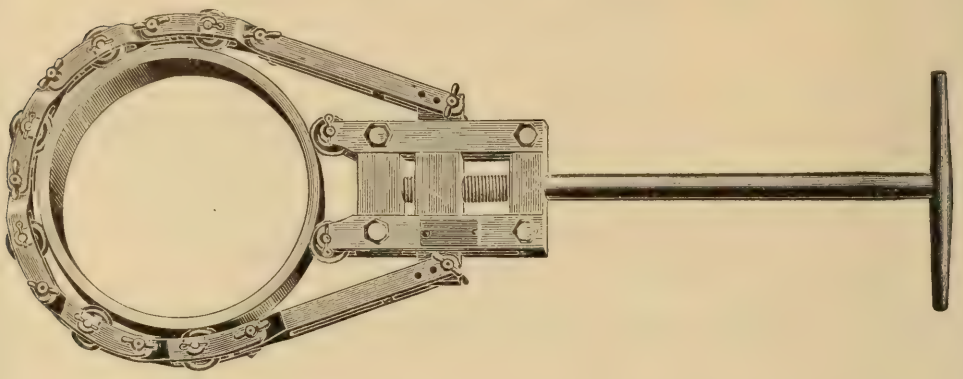

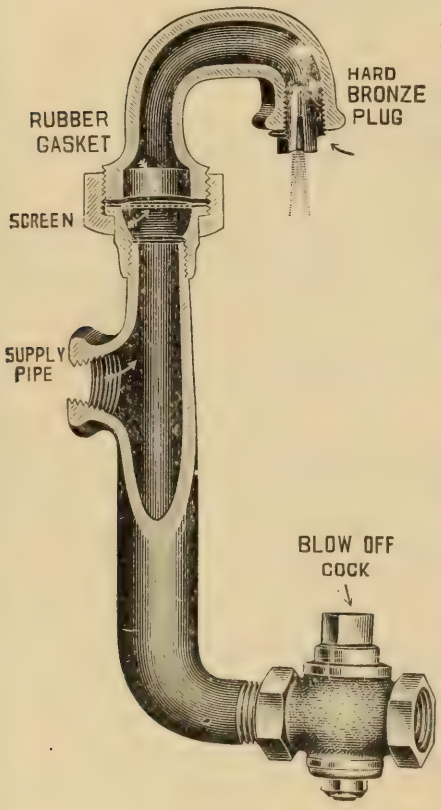

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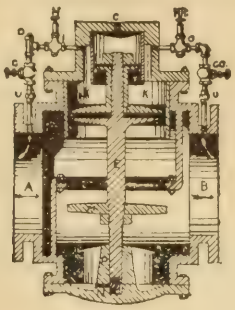

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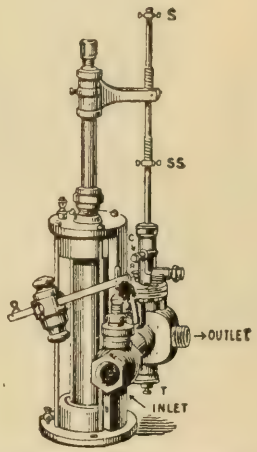

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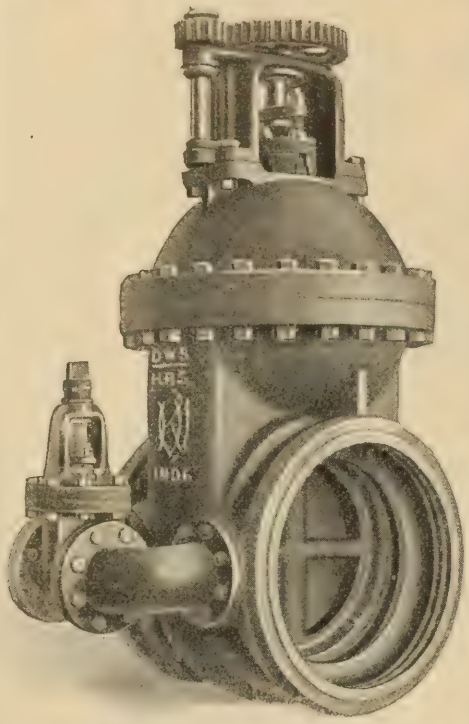

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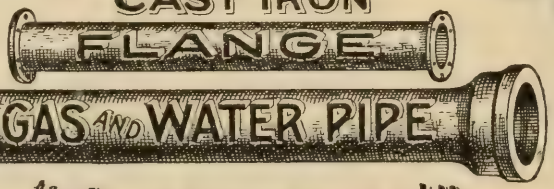

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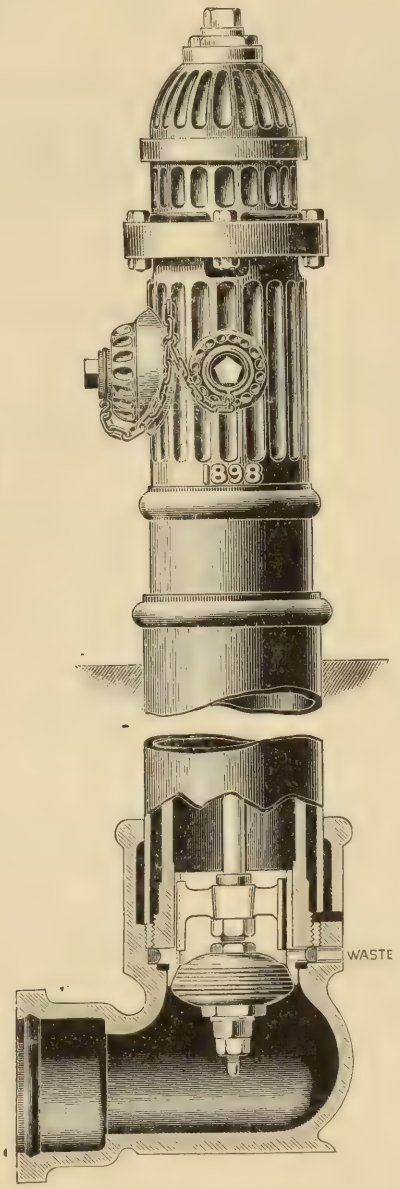

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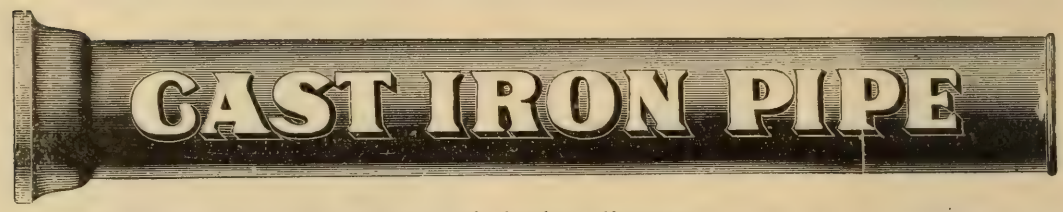

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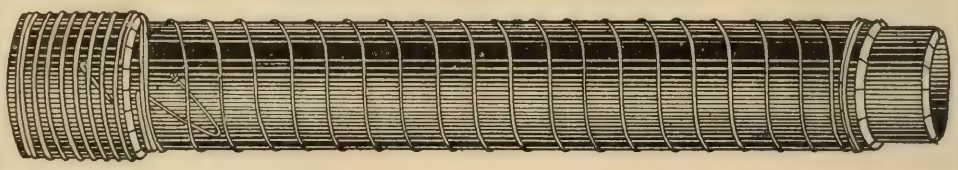

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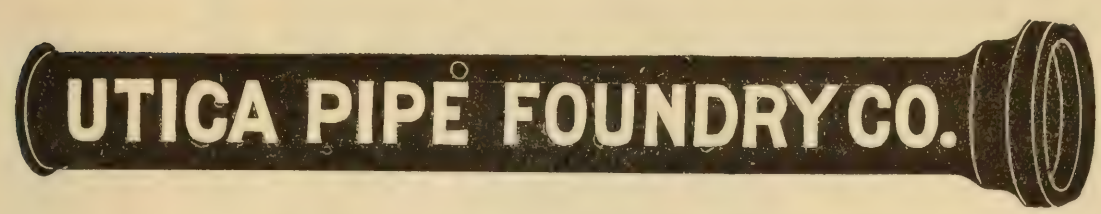

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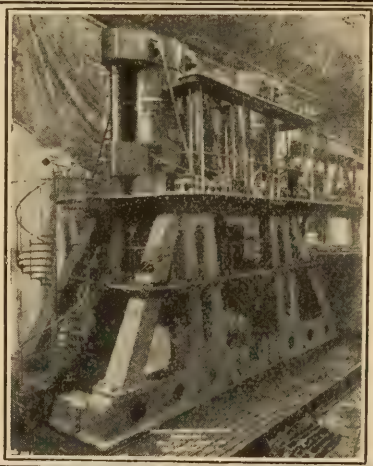

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